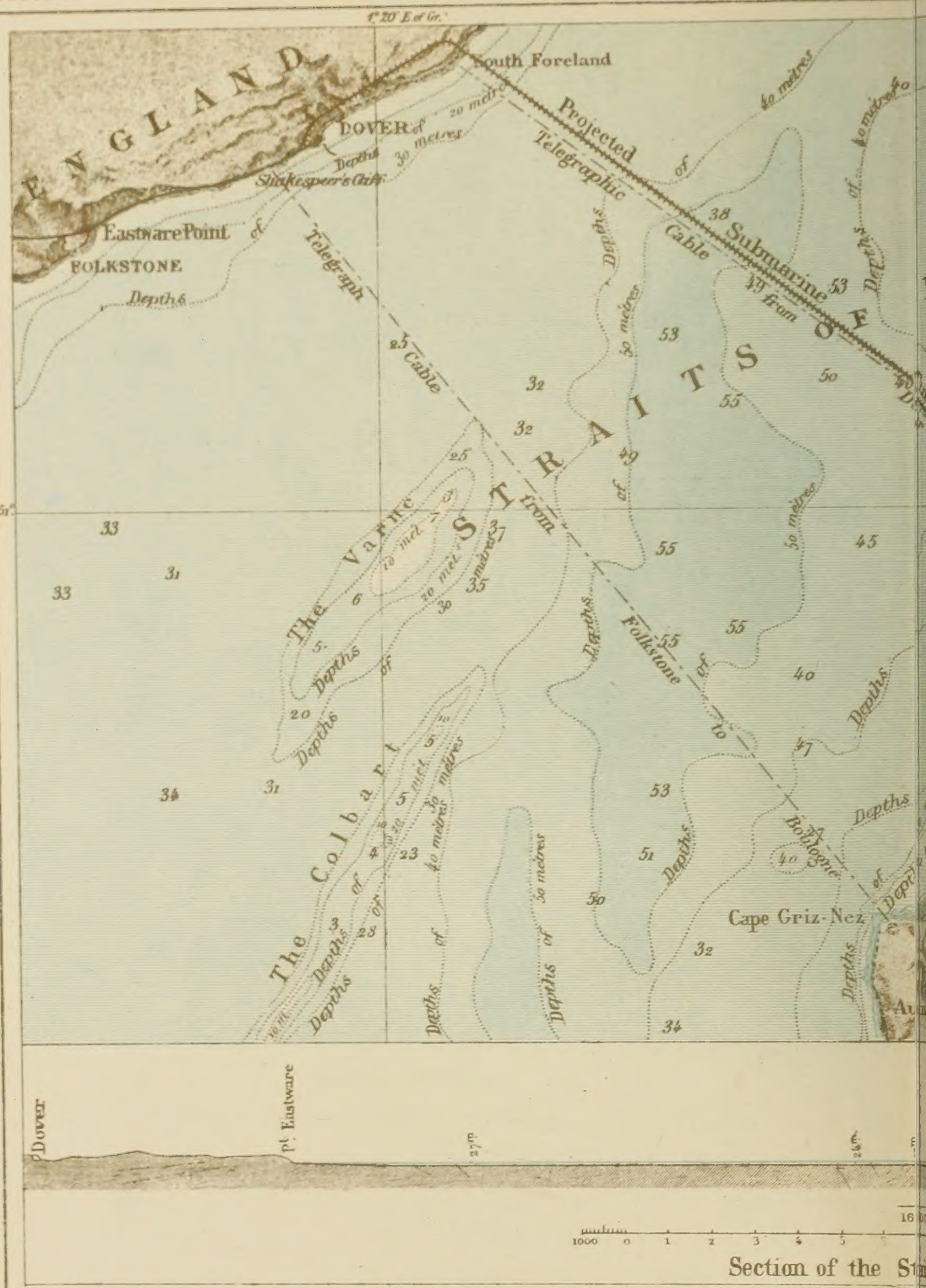
The Universal Geography

WITH ILLUSTRATIONS & MAPS.

THE OCEAN

THE OCEAN

STRAITS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A NEW
PHYSICAL GEOGRAPHY

By ÉLISÉE RECLUS

EDITED

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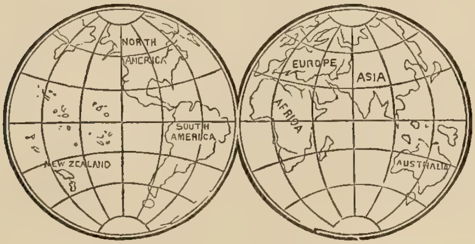
IN TWO VOLUMES

Vol. II.—THE OCEAN

A DESCRIPTIVE HISTORY OF THE PHENOMENA OF THE LIFE OF THE GLOBE

Illustrated by numerous Engravings and Maps



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THE OCEAN;

THE ATMOSPHERE, METEORS, AND LIFE.

Part I.

THE OCEAN.

CHAPTER I.

GENERAL CONSIDERATIONS.

TO the majority of mankind grouped in crowded populations on the continents, occupying scarcely a quarter of the surface of the globe, the sea is little else than a vast abyss without limits or bottom. Even learned men are inclined, by an illusion of mental perspective, to give a much greater geographical importance to the phenomena of continental regions, than to those of the ocean. So also our ancestors, beholding infinite space filled with stars and nebulæ arched over their heads, imagined this immensity to be a dome resting on the vast structure of the earth.

The ancients, says Mr. John Murray in his recent address at the Aberdeen meeting of the British Association on "The Great Ocean Basins," down to the time of Aristotle, and most of them for a long time afterwards, regarded the earth as a great plain surrounded on all sides by the mighty, deep, gently-flowing stream of the ocean. In the geography of the Homeric age there was not supposed to be any communication between the Mediterranean and this all-encircling river. When, in consequence of the excursions of the Phœnicians, the communication through the Pillars of Hercules became known, ideas respecting the outer sea gradually changed. At first, curiously enough, the Atlantic Ocean was regarded as muddy, shallow, and little agitated by the winds, a belief apparently associated with the supposed subsidence of the legendary island of Atlantis. The world, as known to the ancients down to three hundred years before Christ, is represented in the map of Hecatæus.

There seems to be no doubt that the spherical form of the earth was known to some of the philosophers even before the time of Aristotle; but these have been few in all ages, and an idea so directly opposed to the apparent evidence of the senses could only be expected to win its way with difficulty. Indeed, at the present day the majority of even educated people are unable to give any reason for their belief that the earth is a sphere, other than that navigators are now in the habit of sailing round it.

However, we find that Eratosthenes, Posidonius, and other learned Greeks, who flourished between one and two centuries before our era, were in possession of ideas concerning the figure and position of the terrestrial globe which do not differ materially from those of the modern geographer. They had considerable knowledge of the great wide sea, a clear perception of the diurnal recurrence of the tides, of their monthly cycles of variation, and correctly ascribed these changes to the influence of the moon. They speculated on the circumnavigation of the globe, and thus anticipated by many centuries the project of Columbus of sailing direct from Spain to the Indies.

During the century immediately preceding the Christian era, and during the dark and middle ages, there was a large acquisition of information with respect to the superficial extent of the ocean. But, when we look back on the history of knowledge concerning our planet, there is to be found no parallel to the impression produced in men's minds and conceptions by the discovery of America, and the circumnavigation of the world, a few years later, by Magellan and Drake. The influence of these events and the great ideas associated with them, can be traced throughout the literature of the Elizabethan period; Shakespeare appears to have had the mental picture of the great, solid, floating globe continually before him. His spirit seemed—

> ". . . . blown with restless violence round about
> The pendant world."

To the great mass of people the circumnavigation of the globe was the practical demonstration that the earth was swung in space, supported alone by some unseen power; it was the conclusive proof of its globular form—a fact which must be regarded as the fundamental principle of all scientific geography.

The rage for geographical exploration which set in after the discovery of America brought the phenomena of the ocean into greater prominence, but the science of the sea can hardly be said to have commenced till the seventeenth century, when Hooke and Boyle undertook their experiments as to the depth of the sea and the composition of ocean water; and several naturalists gave descriptions of the animals and plants inhabiting the shallow waters surrounding the land. During the eighteenth century there was again a large acquisition of knowledge concerning the ocean, for the navigator was busy with the study of the winds, currents, and tides; while the two Rosses, with other explorers and scientific men, made most praiseworthy endeavours to investigate the greater depths of the sea, during the first half of the present century.

The vast abysmal regions of the great ocean basins, however, lay all scientifically unexplored, when about twenty years ago their systematic examination was undertaken by expeditions sent forth by England and by the Governments of the United States, Germany, Italy, France, and Norway.

It is not easy to estimate the relative importance of the events of one's own time, yet in all probability the historians of the reign of Victoria will point to the recent discoveries in the great oceans as the most important events of the

century with respect to the acquisition of natural knowledge, as among the most brilliant conquests of man in his struggle with nature, and doubtless they will be able to trace the effect of these discoveries on the literature and on the philosophic conceptions of our age. A mantle of mystery and ignorance has been cleared away from the eleven-sixteenths of the earth's surface covered by the ocean, and in its place we have much definite and accurate knowledge of the depths of the sea. The last of the great outlines showing the surface features of our globe have been boldly sketched; the foundations of a more complete and scientific physiography of the earth's surface have been firmly laid down.

Although the influence of the ocean in the general economy of the globe has not been studied with the same relative care as the effect of the rivers which flow through the plains, or of the springs which gush from the clefts of the hills, yet it is still of the first importance, and on it all the phenomena of planetary life depend. "Water is the chief of all!" exclaimed Pindar in the early days of Hellenic civilization; and since then science has revealed to us, that the continents themselves are elaborated in the bosom of the seas, and that without them earth, like a metallic surface, could give birth to no organic life whatever. Thus, as almost all the cosmogonies of primitive nations poetically declare, earth is "The daughter of ocean."

This is not simply a myth, it is a fact. The study of the strata of the earth—rocks, sand, clay, chalk, conglomerates, proves that the materials of the continental masses have in great part been deposited at the bottom of the sea; where they have assumed their form and character. Many rocks, especially the granites of Scandinavia, which were formerly believed to have emerged in a plastic state from the interior of the earth, are perhaps in reality ancient sedimentary strata slowly transformed by mechanical and chemical action, which operate incessantly in the great laboratory of the globe. Even on the sides and summits of the highest mountains, now raised thousands of feet above the level of the ocean, may sometimes be found traces of the action of the sea in ancient times. Under our very eyes the immense work of creation, commenced by the seas in the earliest epoch, is carried on without relaxation; with such energy, in fact, that even during this short life man may witness important changes along their shores. If the waves undermine and slowly destroy a peninsula here, elsewhere they spread out sandy beaches and form islets. New rocks, differing in arrangement and appearance, succeed the ancient rocks demolished by the waves. Thus the promontories of granite are disintegrated by the action of the waters, which carry away its various constituents, quartz, felspar, and mica, building them up into new rocks. In the same way the clay resulting from the slow decomposition of the porphyritic or granitic felspar is transformed into slate, which becomes sooner or later as hard as the ancient schists. But the dashing waves and running waters are not the only agents occupied in the formation of new rocks in the bosom of the sea. There is another ever active agent engaged beneath its waters. This agent is animal life. Shells, corals, and innumerable animalculæ with calcareous or silicious coverings, inhabiting the ocean, are incessantly engaged in consuming and reproducing. They absorb and digest matter which the rivers bring down to the sea, and secrete substances which form their skeletons and cases: as, generation after generation, these swarms perish, their remains are spread out over the bottom of the sea or heaped up on its shores; and at last form immense banks and submarine plateaux which by some subsequent elevation will be brought to light.

Owing to this ceaseless renewal of the rocks, the ocean is constantly creating a

world differing from the old one in the appearance and the disposition of its beds. Thus, to the geologist, the invisible depths of the sea should not be of less importance than the exposed surface of the continents. The ground which to-day bears us and our cities, will disappear as the continents of former epochs have already entirely or in part disappeared; and the unknown spaces which the waters now cover will rise in their turn, and appear as continents, islands, or peninsulas.

In the long period of geological centuries or ages during which the lands are bathed, not by the waters of the sea, but solely by the waves of the atmosphere, the ocean does not the less continue to modify the configuration of the globe by its clouds, its rains, and all the meteoric influences which take their birth at its surface. All those atmospheric agencies which rage about the summits of mountains, riving them and little by little lowering them, it is the sea which despatches them. All those glaciers which polish the rocks, and carry down into the valleys those piled-up boulders, it is the clouds from the ocean which deposit them in the form of snow on the summits of the mountains. All those waters which penetrate by fissures into the depths of the ground, which dissolve the rocks, hollow out the caverns, bring mineral substances to the surface, and cause at times great subterranean subsidences, what are they, but marine vapours returning in a fluid state towards the basin from whence they arose? Finally, the numerous rivers which spread life over all the globe, and without which the continents would be deserts wholly uninhabitable, are nothing else than a system of veins and veinlets, which carry back to the great reservoir of the ocean, the waters distributed over the soil by the arterial system of clouds and rain. It is, then, to the phenomena of this oceanic life we must attribute the immense geological operations of rivers, and the exceedingly important part which they play in the flora and fauna of different countries, and in the history of humanity itself. The future discoveries of geologists and naturalists will tell us also what share in the production and development of those germs of vegetable and animal life, which reach their greatest beauty on continents, may be referred to the ocean.

As for climate, upon the varieties of which all that lives upon the earth depends,—does it not follow from movements of the ocean, as well as from the position and elevation of the masses of land? The cold of polar latitudes would be more rigorous, and the heat of the tropics more intense, and these extremes would undoubtedly destroy most of the beings now in existence, if the currents of the ocean did not convey water from the poles to the equator, and from the equator to the poles; thus constantly tending to an equalisation of temperature. In the same way, the atmosphere of continents would be completely deprived of vapour, and so perhaps rendered unfit for breathing, if the humidity it derives from the sea were not spread by the winds all over the globe. Thus the ocean blends the contrasts of climate, and makes an harmonious whole of all the distinct regions of our planet; it awakens and preserves life on the earth, which it has deposited layer by layer, which it waters by its vapours, and renders fertile by its springs and its rivers.

When it is remembered that the extreme depth of the ocean, as will presently be seen, is only about five miles, and that the height of the highest mountain stands also at about the same elevation above sea-level, while the diameter of the globe itself is no less than 8,000 miles, the comparative insignificance of all the surface inequalities of the earth is at once made obvious. As Mr. John Murray observes, a circle sixty-six feet in diameter, having on its surface a depression of one inch; or a globe one foot in diameter, with a groove on its surface one-sixtieth of

an inch in depth, would represent on a true scale the greatest inequality of mountain height and ocean depth on the earth's surface.

Misconceptions often arise, and erroneous conclusions are frequently arrived at when these proportions are not rigidly borne in mind. But, unimportant as these surface features may appear when viewed with reference to the diameter of the earth, or to the superficial area of an ocean several thousand miles in extent, still, to the geologist and physical geographer the elevations and depressions, foldings and dislocations, vertical and lateral, which form these inequalities, are truly gigantic, immense, profound; and the more they are studied the more do they appear to be the result of changes taking place in a very definite and orderly manner in the course of the earth's developmental history.

The dark-coloured masses of continental land are, at some one point, more or less closely connected with similar masses; there is usually a place where adjacent masses are not separated by oceans of very great depth. A traveller might almost journey from any one point in these regions to any other without once losing sight of land. If an exception must be made to this statement, it is in the case of New Zealand and the Antarctic continent, for the *Challenger's* dredgings, which brought up masses of schist, gneiss, granite, sandstone, and compact limestone along the borders of the ice barrier, show beyond all doubt that there is a mass of continental land at the south pole, but, since it is buried beneath perpetual snow, its exact extent is a matter of conjecture.

The surfaces of the continents are everywhere cut into cliff and gorge, mountain and valley, and are continually undergoing a process of disintegration. Water, frost, ice, sudden changes of temperature, are ever tearing the solid rocks to pieces, rivers are transporting the fragments down to the ocean, or carrying away the solid earth in solution; the bulk of this material is deposited in the areas bordering the continents—the uncoloured areas on the maps—there to form rocks which may once again become dry land. Sooner or later the whole of the continents would in this way be reduced below the level of the waves, were not other forces at work producing elevation. Such forces there are, and they are probably more potent than the disintegrating and transporting forces, since there are many reasons for believing that there is now more dry land than at any other period of the earth's history.

The continents have an average height of about 900 feet above the level of the sea; they may be regarded as elevated plateaux occupying five-sixteenths of the earth's surface.

The abysmal regions of the earth occupy eight-sixteenths, or one-half of the earth's surface, and have an average depth of three miles beneath the surface of the waves. The greatest depths in the Pacific are to the south and east of Japan, where there are abysses of over five miles; and in the Atlantic the greatest depth is to the north of the Virgin Islands, where there is a depression of a little over four miles.

From all we yet know of these abysmal areas they have not a diversity of peak, gorge, mountain, and valley comparable to those which are met with on land; they are fundamentally areas of deposition. It is true that the close soundings of telegraph engineers appear to show that in some cases there may be steep cliffs in the shallower depths of the ocean in volcanic areas; yet the general aspect of the abysmal regions must be that of vast undulating plains, interrupted here and there by huge volcanic cones, with slopes at a very low angle. When these cones rise above the surface they form volcanic oceanic islands. When they rise nearly to

the surface they are, in the tropics, often capped by coral atolls; but many of them are far beneath the waves and are covered by a white mantle of carbonate of lime—the dead shells and skeletons of pelagic and deep-sea organisms.

The surface of the earth may then be divided into three great regions—the abysmal area, occupying, so to speak, the bottom of the basins, covering one-half of the earth's surface; a border region occupying, so to speak, the sides of the basins, covering three-sixteenths of the earth's surface; and lastly, the continents, which cover five-sixteenths of the earth's surface. The average height of the elevated plateaux of the continents above the submerged plains forming the abysmal regions is fully three miles

CHAPTER II.

OCEANIC BASINS.—DEPTH OF THE SEA.—LEVEL OF THE SURFACE OF THE OCEAN.

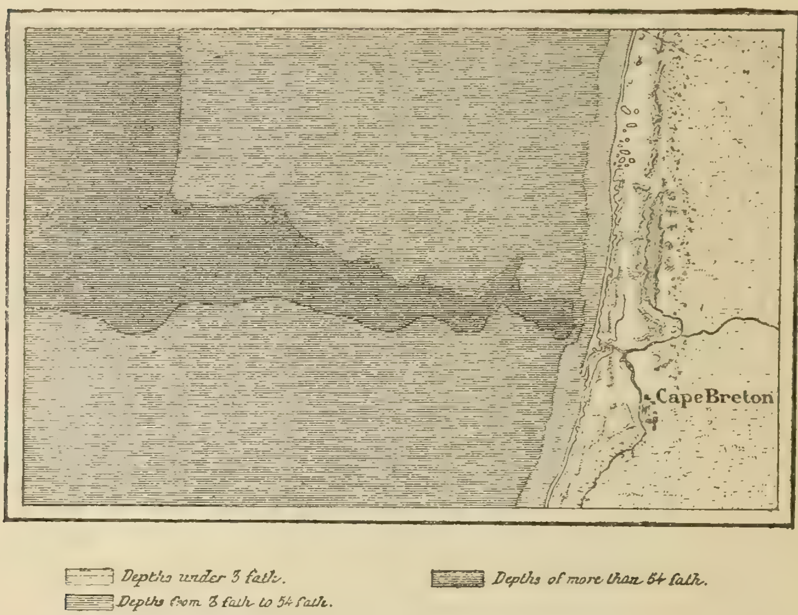
THE seas which cover the greater part of this planetary sphere have not completely enclosed basins. They all have their origin in the great common reservoir of the Antarctic Ocean, and communicate with each other by wide straits, or by sheets of water of secondary importance. This partial absence of boundaries, and their enormous extent of surface, deprive the seas of that harmony of form observable in the continental masses. Yet, whenever the water washes the shores of the land, it necessarily reproduces its contour ; and, in consequence, the sea everywhere presents a distribution exactly the opposite of that of the earth. The twofold basin of the Atlantic with its wide central expansion, corresponds to the two continents of America with their narrow uniting isthmus. The Pacific itself is divided by its immense Archipelago into two vast distinct seas ; and the Indian Ocean in the south balances the mass of Asia in the north. Whilst limiting with its waves the shores of the land, the ocean penetrates far into the interior, either by large rounded gulfs like those of Guinea and Bengal, or by seas bordered with chains of islands and islets, like the China sea and that of the Antilles, or by an intricate network of channels like those of Sunda, and the Polar Archipelago of America. Certain seas also are almost completely enclosed, and communicate with the remainder of the ocean only by narrow outlets, as is the case with the Mediterranean and the Red Sea.

The bottom of all these seas is not always horizontal or even regularly inclined. It is certain that the bed of the sea has, like our continents, but in a far less degree, plateaux, valleys, and plains. Geology reveals to us that in the course of ages the highlands of the continents sink beneath the oceanic expanses, and the abysses formerly hidden by their waters emerge to the light and reveal the inequalities of their surface. Were not the plains and the hills, which now bear our cities and our harvests, in past ages covered by the waters of the deep? Do we not see on the flanks of the Himalayas, 18,000 feet above the level of the mouth of the Ganges, shells which the sea has there deposited in the strata? And do not our navigators search the bottom of the ocean, and, so to speak, investigate its inequalities with those enormous "feelers," their sounding apparatus?

We may well imagine that the submarine surface still preserves all its primitive rudeness; and that its rocks, cliffs, and fells uniformly present edges unworn and sharp, the marks of fracture, just as on the day when the solid rock was first cleft.

And, in fact, in the depths of the sea there are no frosts to break off projecting peaks, no lightnings to split, no glaciers to carry them or crumble them away, no meteoric influences to corrode and round them. Nevertheless, if there are not in the sea, as on the land, agencies like these, ceaselessly at work levelling projections, there are others which as ceaselessly labour to smooth the asperities of the surface. There are the sedimentary deposits brought down by the rivers; and innumerable millions of the skeletons of animalculæ, which live in the deep, or fall like snow from the upper strata of the water and gradually fill up the submarine valleys. Those fantastic mountain-chains drawn on the bed of the sea by Buache and other geographers cannot therefore really exist, since the geological agencies at work under water differ from those which carve out the table-lands and mountains on our continents. If some immense eddy prevented the particles from being deposited in the deep parts of the ocean, then the rocks and the rifts of the abysses

Fig. 1.—Gulf of Cape Breton.



would keep their first form, like those peaks and craters of the moon which are not worn away by the inclemencies of an atmosphere. There are, indeed, tracts in the sea where, perhaps from the influence of a submarine counter-current, the rocks of the bottom are not covered by organic alluvium. In the deepest part of that great arm of the sea which separates the Faröe Islands from Great Britain, Wallich drew up from a depth of more than 600 fathoms a large fragment of quartz detached from the living rock, and several pieces of basalt; it is quite possible, however, that these fragments had been dropped there by an iceberg. Pieces of lava have also been fished up off the south coast of Iceland.

In general, the sea-bed extends for wide spaces in long undulations and gentle slopes. Sailors, who are carried swiftly over the water by wind or steam, and who generally take soundings at places far distant from one another, are tempted to exaggerate the magnitude of inequalities in the sea-bed, and to see chasms and precipices where the declivity is in reality inconsiderable. Escarpments similar

to those of the continental mountains very rarely present themselves; Fitzroy was greatly surprised to find in the neighbourhood of the Abrolhos, near Brazil, such rapid slopes, that the lead on one side of the ship indicated from 4 to 6 fathoms only, while on the other side it marked from 16 to 22 fathoms. Sometimes a special cause explains these abrupt changes of the level. Thus M. de Villeneuve-Flayosc discovered in the Gulf of Cannes a spring of fresh water springing from the depths of a kind of well, the sides of which sloped at an angle of 27 degrees. But how can we explain that singular gulf which extends immediately in front of Cape Breton on the coast of the Landes? Ought we to attribute its formation to the meeting of the tides which takes place in the channel of the Bay of Biscay? This is a question which it is not yet possible to decide.

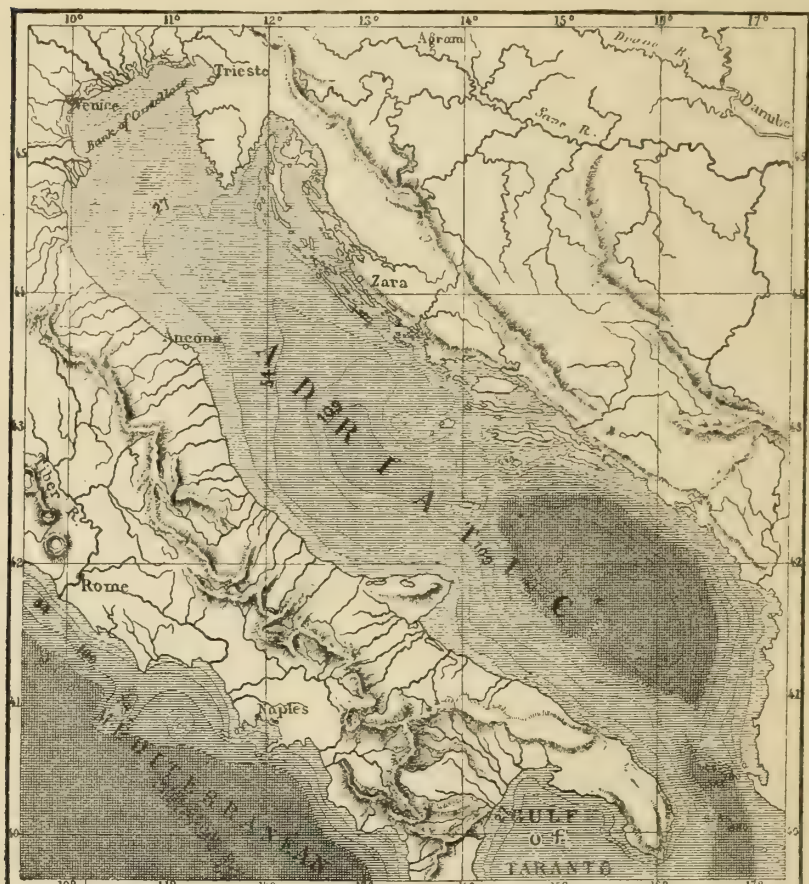
We can form some notion of the submarine tracts by surveying the countries that have emerged from under water at a comparatively recent epoch. The Landes of France, the low lands which have replaced the Gulf of Poitou, a great part of the Sahara, the pampas of La Plata, furnish remarkable examples of the regularity of inclination which generally characterises the bottom of the sea. Even rocky coasts, like those of Scotland and Scandinavia, have been levelled here and there in their lower parts, that were not long ago covered by the waters of the Atlantic.

If earthquakes and fissures of the soil, volcanoes and slow oscillations of the terrestrial crust, did not on their side increase the inequalities of our planet's surface, it is certain that the incessant contribution of fluvial deposits, the fragments of rocks worn away by the waves, and above all those remains of swarming organisms which fill the sea, would have effected as an inevitable result the equalisation of the ocean-beds, and the transformation of their abysses into scarcely indicated slopes; the waters, on their side, would gradually invade the surface of the continents, till, after the operations of myriads of centuries, the earth would become again what it formerly was, a spheroid with its surface entirely covered by a bed of water of uniform thickness.

According to an ancient popular opinion, which, in default of direct observation, was not more contradictory to good sense than many other hypotheses called scientific, the sea was "bottomless;" and this proverbial expression is still that which best conveys to many ignorant persons the real state of things. At the commencement of last century Marsigli himself spoke of "the abyss" of the Mediterranean as of a gulf absolutely unfathomable. On the other side, mathematicians, supported by theoretical considerations, have attempted to estimate by calculation the average depth of the seas. Buffon, who does not quote the Italian author from whom he has borrowed his argument, gave to the ocean a depth of water equal to 230 toises, or 240 fathoms. The astronomer Lacaille, whose estimates are no nearer those that recent soundings have rendered probable, allowed from 164 to 273 fathoms of depth to the sea. Laplace, who erroneously estimated the mean elevation of the land at 3280 feet (that is to say, three times the height now approximately determined), thought that the waters of the sea must also be of about equal depth. Young, drawing his deductions from the theory of the tides, assigned about 2735 fathoms to the waters of the Atlantic, and from about 3250 to 3800 fathoms to those of the South Sea. Arnold Guyot remarked that this depth assigned to the Atlantic, would be in fact that of the trench formed in this marine valley, between the coasts of South America and Africa, having the plateaux of Bolivia on the one hand, and those of the Lupata mountains on the other. This last estimate has, however, only a relative value: if we apply it to the Pacific,

continuing westward and eastward the coasts of Asia and America, we should find as the lowest point, and lying (according to this hypothesis) to the east of Easter Island, a depth of about $15\frac{1}{2}$ miles, three times the elevation of the highest mountain in the world. Evidently it is by direct observation that we must hope, some day, to know all the projections and undulations of the bottom of the ocean; but the instruments which seamen can command are still imperfect, and, except for inconsiderable depths, do not give results of rigorous accuracy. In those latitudes where the water is many hundreds or even thousands of fathoms in depth, they

Fig. 2.—Depths of the Adriatic.



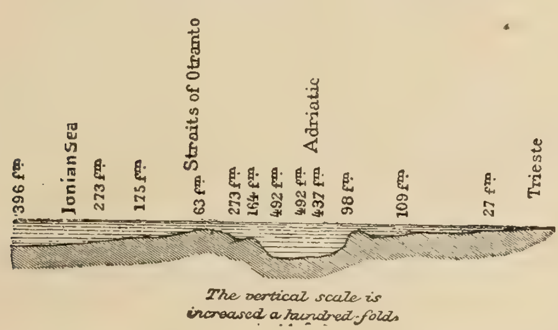
(The parts marked by cross-shading are 270 fathoms and upwards in depth.)

cannot risk the taking a sounding unless the atmosphere and the waves are in an exceptional state of tranquillity; and even then the slenderness of the cord, the weight of the apparatus, the enormous pressure it endures as it descends, and which increases at the rate of one atmosphere for every 11 yards of immersion, and finally, the long hours which must be employed in this delicate operation, greatly endanger the final success. Unless instruments furnished with electrical bells, like those of Schneider or of Gareis and Becker, and others more easily employed, more rapid and sure, are used, "bathymetric" observations will be always at great distances from each other, and it will not be possible to construct a submarine map

in relief, such as is being constructed of the surface of the continents. Besides, it is very rarely that sailors take soundings in the deep seas simply for the scientific pleasure of investigating the depth of the ocean. It is solely for the requirements of navigation, of commerce, and of industry, that they have observed the depth of the sea, either in gulfs like the Adriatic, or in parts that are filled with sandbanks like the North Sea, in the neighbourhood of coasts and rocks laid down in ancient maps, or in those parts of the ocean which are destined to receive electric cables. In the open sea ships sail almost entirely over unmeasured depths.

Owing to its elongated form and to the amphitheatre of lofty mountains which all but wholly surround it, the Adriatic offers a very remarkable example of the continuation of the continental slopes below the level of the sea. The bed of the northern part of this gulf, which is a continuation under water of the level plains of Venetia, has an exceedingly gentle slope, much less, in fact, than that of the plains of Lombardy, which seem horizontal. The sounding-lead shows only a depth of 54 fathoms beyond the narrows formed by the islands of Zara and the headland of Ancona; thus more than a third of the Adriatic is found not to exceed in mean depth rivers like the Mississippi and the Amazon. Farther south the submarine declivity, which continues on one side that of the Apennines, on the other that of the

Fig. 3.—Profile of the Bed of the Adriatic.



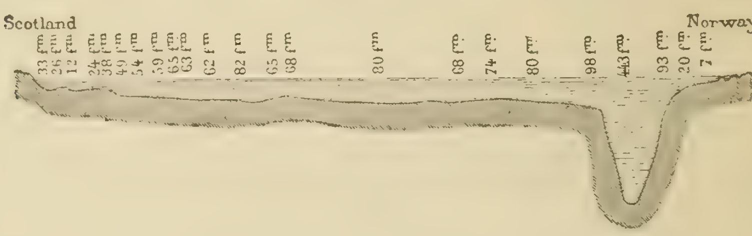
Alps of Dalmatia, becomes comparatively greater, and the sounding-lead descends to about 110 and even 170 fathoms below the surface. At this spot the sea forms a sort of hollow, bounded on the south by a submarine isthmus uniting the peninsula of Manfredonia with the isolated rock of Pelagosa, and with the islands of the Dalmatian coast, Lagosta, Curzola, and Lesina. Beyond this isthmus, and extending as far as the Straits of Otranto, is another and much deeper hollow, towards the middle of which the soundings indicate a depth of nearly 500 fathoms; and on the east rise the precipices of Montenegro, the roots of which descend very rapidly beneath the waters. Thus the soundings of the Adriatic confirm the observations, made long ago by Dampier and many other navigators, that the sea is generally deep at the base of abruptly sloping mountains; and, on the other hand, that there is but a slight depth of water near low coasts.

Of the Mediterranean, properly so called, the bed is almost unknown, except in those parts which have been explored for the laying of telegraphic cables; however, on comparing with one another all the soundings, and the various tracks followed by those who have laid the wires, we can at least form a general notion of its submarine surface. If the waters of the Mediterranean were suddenly lowered about 110 fathoms it would be divided into three distinct sheets of water:

Italy would be joined to Sicily, Sicily would be united by an isthmus to Africa, the Dardanelles and the Bosphorus would be closed, but the outlet of Gibraltar would remain in free communication with the Atlantic Ocean. If the level was lowered by about 550 fathoms the Ægean, the Euxine, and the Adriatic would wholly disappear, or only leave in their beds unimportant pools; the remainder of the Mediterranean would be divided into several seas like the Caspian, either isolated, or communicating with each other by narrow channels, and the terminal promontory of Europe would be joined by the isthmus of Gibraltar to the mountains of Africa. A depression of about 1100 fathoms would leave nothing but three inland lakes; to the west a triangular basin occupying the centre of the depression between France and Algeria; in the middle, a long cavity extending from Crete to Sicily; and eastward, a hollow lying in front of the Egyptian coast. The greatest depth of the Mediterranean, exceeding 2200 fathoms, lies to the north of the Syrtes, almost in the geometrical centre of the basin. The ancients supposed it lay in the Sardinian waters, where, according to Posidonius, a depth of 1200 fathoms was recorded.

It is the same with the North Atlantic Ocean as with the Mediterranean. The depth of the central valley, extending from north to south between Europe and the New World, is known only in a general manner. But the gulfs and

Fig. 4.—Profile of the bed of the North Sea, from the north point of Scotland to Stavanger in Norway.

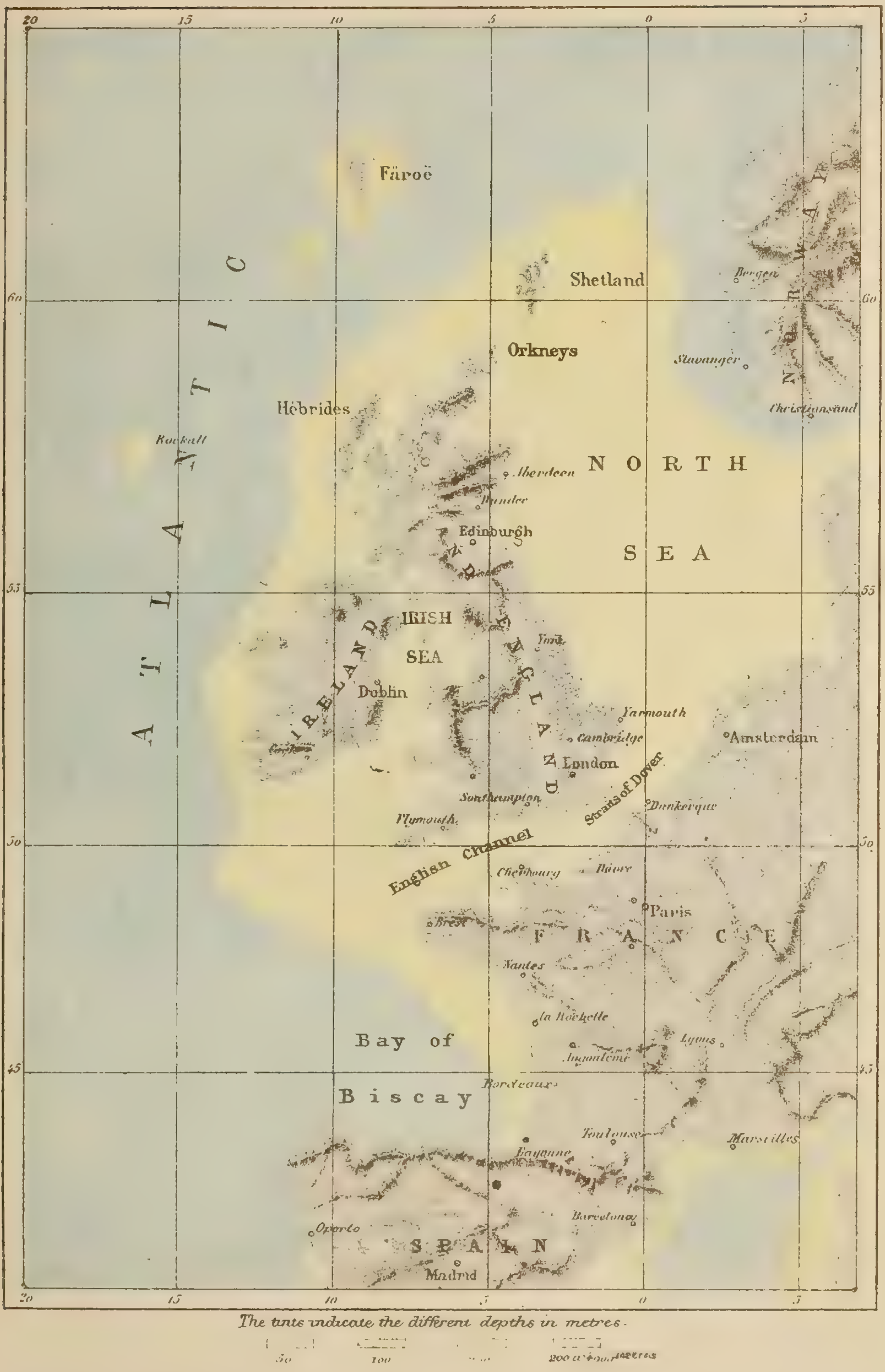


straits which project from the ocean between the northern countries of Europe, such as the Channel, the North Sea, the Cattegat, the Baltic, have been almost completely explored by the sounding-lead.

The North Sea in all its northern part, from the 51st to the 57th degree of latitude, presents a mean depth of only about 16 to 27 fathoms, except near Newcastle-upon-Tyne, where the bottom is found to be from about 49 to 65 fathoms below the surface. Vast tracts of sand and mud—the White bank, the Black bank, the Brown bank, the Dogger bank, the Fisher bank, separated from one another by fosses and lateral channels, deeper by from about 6 to 11 fathoms—almost entirely fill its bed, and stretch as far north as the Shetland Islands. There, as in the centre of a whirlpool, is deposited the marine alluvium, whilst that arm of the ocean follows the precipitous shores of Scandinavia over the rocks and compact clays of the bottom. In these parts the lead descends to about 164 and even 437 fathoms from the surface of the sea; and in the centre of the Skagerrack, between the sand beach of Jutland and the bold shores of Norway, nearly 433 fathoms have been reached. One seems to see here, in vaster proportions, a repetition of those narrow and deep trenches which surround isolated rocks left standing out on flat sandy shores.

From the Skagerrack to the Cattegat, which may be considered as the sub-

SUBMARINE PLATEAU OF THE BRITISH ISLES.



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marine threshold of the inland waters of the Baltic, the transition is effected somewhat abruptly. The Cattegat presents nowhere more than 93 fathoms, the mean depth of its channel is only 54 fathoms, and the banks of sand and mud render its navigation difficult. The depth of water is reduced to 16, 11, and even in some places to 5 fathoms, in the Sound and the Great Belt, which form the entrances to the Baltic Sea, properly so-called. This vast reservoir, which partakes at the same time of the nature of a gulf by its free communication with the ocean, and of an inland lake by the slight saltness of its waters, has a mean depth of 22 to 33 fathoms, analogous to that of the Cattegat. According to Foss, the greatest depth (between the island of Gothland and Esthonia) would be found at only 98 fathoms below the surface of the sea; but according to Anton von Etzel, the lead would not reach the bottom at less than 150 fathoms in the deepest hollow.

Fig. 5.—Depths of the English Channel.

To the south-west, the North Sea communicates by the Straits of Dover with the Channel, a narrow arm of the sea which may be considered as a mere accident of the earth's surface, as a kind of maritime trench, so inconsiderable is its depth compared with that of the ocean. In order to form a true notion of the depth of the Channel, compared with its width, one must imagine a miniature of this sea drawn on a scale of one yard for two-thirds of a mile, on a perfectly horizontal surface. This sheet of water would not have less than 547 yards of length, and its width would vary, according to the coast lines, between 36 and 240 yards. And yet, notwithstanding this considerable surface, the greatest depth would be less than 2 inches at the entrance. In the deepest hollow of the Channel, between the hillock representing Start Point and that of the Sept-Iles, it would be less than 2½ inches. A sparrow could hop this miniature sea. We see that it is as easy to exaggerate the importance of the depth of the sea as it is the height of mountains.

The section annexed to Plate I. shows the proportionate depth of water between the shores of Dover and Calais.

On leaving the Channel, the parts of the oceanic bed which have been explored by sounding are more and more distant towards the west, and then become quite rare. Finally, many hundred miles out at sea, where the true abysses commence, soundings have been only taken at intervals of about 30 and even 55 miles apart. The points thus marked which have served for drawing the submarine chart of the North Atlantic, are therefore by no means numerous, but nevertheless we have in it a pretty exact representation of the *relief* of the ocean-bed. The average depth of water which separates the coasts of North America and those of Europe is about 1915 fathoms, but the central valley presents a surface relatively uniform, and much less varied than that of Europe or even the United States; the greatest slopes do not probably exceed those of the river-beds which seem nearly horizontal; and it may be said that the depth of the sea is concentric with the surface. Hence the name of "the telegraph plateau," given by Maury to these plains, some time before the first transatlantic cable was laid. The most considerable depth of this plateau is 4846 yards, that is to say, about a 1639th of the width of this ocean; this being a thickness relatively less than that of the finest needle. The section on Plate III. enables us to compare the relief of the continental surface and that of the oceanic depths from the coasts of the United States to those of Europe. It is true that in order to render the vertical dimensions visible, it has been

Fig. 6.—Profile following the Line of the Greatest Depth.

necessary to exaggerate them in the enormous proportion of twenty-fold. To the south the depth of the sea becomes more and more varied. An imaginary section from the plateau of Anahuac to Senegambia across Yucatan, the Caribbean Sea, the Antilles, and the central basin of the tropical Atlantic, presents a much more unequal surface than that of the telegraphic plateau; but the true oceanic part of the basin equally shows a great uniformity in almost its entire extent.

Considered as a whole, the North Atlantic is a depression whose sides descend gradually towards a central hollow situated between the coasts of the United States, the Bermudas, and the Bank of Newfoundland. A fall of the waters of less than 110 fathoms would reveal the submarine groundwork upon which France, Spain, and the British Isles rest. This is indeed the true foundation of the European continent, for immediately beyond this basement which forms the extreme angle of the Old World, the bed of the sea, at an inclination of about eight degrees, descends gradually from 110 fathoms to 1640 and 2187 fathoms below the waves.

The northern slope of the Spanish Pyrenees is continued below the surface of the Bay of Biscay, where depths of over 650 fathoms occur a little north of Santander, whereas a submarine plateau with only 94 fathoms stretches far seawards off Cape Peñas. This plateau, known as that of the Travailleur, from the soundings here executed by MM. de Folin and A. Milne-Edwards in 1880, is all that remains of the isthmus by which, according to Forbes and other naturalists, Spain was formerly connected with Ireland.

A fall in its level of 1094 fathoms would diminish the width of the Atlantic

more than half, would leave the Gulf of Mexico completely dry, and only leave an elongated lake in the central part of the Caribbean Sea. If the present level were lowered by 2187 fathoms, a continent separated from Europe and America by two narrow channels, and extending over a space of from about 1550 to 1860 miles, would stretch into the torrid zone; and, by a remarkable coincidence, would affect that peninsular conformation and southerly direction presented by Greenland, Scandinavia, Spain, Italy, Greece, Arabia, India, and the three great continents of the south. A lowering of 3280 fathoms would completely unite Newfoundland to Ireland, and consequently form a bridge between the Old and New Worlds. Even of the Central Atlantic there would only remain a narrow "Mediterranean" sea in front of the Antilles and Guiana. Finally, let the waters be lowered by 4375 fathoms, and the northern part of the Atlantic would be reduced to a small triangular "Caspian," situated between the Azores, the bank of Newfoundland, and the Bermudas. The greatest depth hitherto reached in the Atlantic is 3900 fathoms, which occurs 94 miles north of the island of Saint Thomas. It is noteworthy that the relatively limited basin of the Caribbean Sea reveals abysses almost equal to those of the broad Atlantic. South of Cuba the deepest point is

Fig. 7.—Section of the Atlantic in the Tropics.

3480 fathoms, while the mean depth of the waters between Jamaica, Cuba, and Honduras Bay is about 2000 fathoms. The low island of Grand Cayman, which rises scarcely twenty feet above the sea, is the culminating point of a submarine ridge some 3000 fathoms high. This abyss of the Caribbean Sea takes the name of Bartlett, from the naturalist who discovered it in the year 1880.

In the present state of science, it is impossible to draw an approximate chart of the depths of the South Atlantic, similar to that which one can construct of the bottom of the northern part. It even appears that many of the soundings made in this part of the ocean must be considered null, because the explorers have not taken into account the deflection of the sounding-line occasioned by submarine currents. The depth of 3600 fathoms obtained by Captain Denham, R.N., has been accepted by M. Bischof and other geologists with some confidence, because this explorer took care to raise the cord several times by a hundred yards, and when thrown again it always stopped at the same point. But the sounding of 8695 fathoms, announced by the American Parker, is certainly erroneous; since later, in the same latitudes, they have found the bottom at 3007 fathoms only. Since then the South Atlantic has been extensively surveyed by the *Challenger* and the *Gazelle,* the former of which traversed it obliquely from the African mainland

to the Brazilian seaboard, and thence by Tristan d'Acunha to the Cape of Good Hope. The *Gazelle* passed from Madeira by the Cape Verde Islands also to the Cape, the greatest depth determined by it being 2870 fathoms, about 480 miles to the south-east of Saint Helena. In the same waters the *Challenger* had touched the bottom at 2520 fathoms. Thus the assumption that the South Atlantic is much deeper than the north has not so far been confirmed. On the contrary, its mean depth appears to be no more than 2500 fathoms, and several banks with 1650 fathoms have been met, especially between the islands of Ascension and Saint Paul.

Before regular soundings were taken, the mean depth of the Pacific was roughly estimated by the velocity of the earthquake waves. In the terrible earthquake of December 23rd, 1854, which partially destroyed several Japanese towns, among others Yeddo and Simoda, the vibrations of the marine surface traversed an oceanic space of 6842 miles in twelve hours and a few minutes; and Prof. Franklin Bache was able to calculate, in consequence, the swiftness of the waves and the depth of the ocean across which they were propagated; this depth is an average of 2346 fathoms. After the earthquake of August 3rd, 1868, on the north-east coast of South America, similar earthquake waves were observed at the Chatham Islands, at New Zealand, Samoa, the Sandwich group, and Newcastle in Australia. From their velocity the mean depth was found to vary from 2750 to 1480 fathoms. In 1877 the underground disturbances at Iquique afforded an opportunity for fresh observations, from which it appeared that along three lines between Peru and New Zealand the mean depth was 770, 760 and 1327 fathoms. A few accurate soundings effected by Lieut. Brooke had already given 2500 fathoms mean depth for the seas in the neighbourhood of Hawaii. But no systematical survey of the whole Pacific had been made until Capt. Belknap, of the *Tuscarora,* was commissioned to explore the waters between California and Japan in connection with a projected submarine cable between the two continents. After surveying the seaboard of the United States, which showed a depth of 110 fathoms within a mean distance of 30 miles from the coast, the *Tuscarora* proceeded by the Sandwich Islands to Japan, returning by the Kurile and Aleutian Archipelagoes round the northern shores of the Pacific to Cape Flattery, at the entrance of S. Juan de Fuca Strait. During these explorations, from August, 1873 to August, 1874, no less than 483 soundings were taken over a distance of some 6000 miles. In some places the slope is comparatively very abrupt, as in the south-west of Japan, where within a few miles the plummet sinks from 1860 to 3650 fathoms. South of the Aleutian Islands the fall is no less than 25 in 550 fathoms; but elsewhere it is much more gradual. Between California and Hawaii it averages 2600 fathoms, which agrees exactly with that deduced from the velocity of the earthquake waves. The deepest abyss in the Pacific occurs on the margin of the Kuro-Sivo stream, off the Japanese coast, where the soundings of the *Tuscarora* revealed 4760 fathoms, the greatest hitherto authentically determined in any ocean. Were Pelion piled on Ossa, and Gaurisankar on both, they would scarcely reach the surface in this profound abyss.

In the Indian Ocean depths of 2930 fathoms have been found during the soundings made in laying the telegraph line between India and Australia. But its gulfs, like those of the Mediterranean and the Atlantic Ocean, have relatively a slight depth of water, the Persian Gulf, for instance, having a mean depth of only 54, and the Red Sea of 163 to 273 fathoms. Those parts of the Gulf of Bengal which are adjacent to the Coromandel coast and the delta of the Ganges, increase only very gradually in depth, except near the northern extremity of the gulf, where a

Ocean

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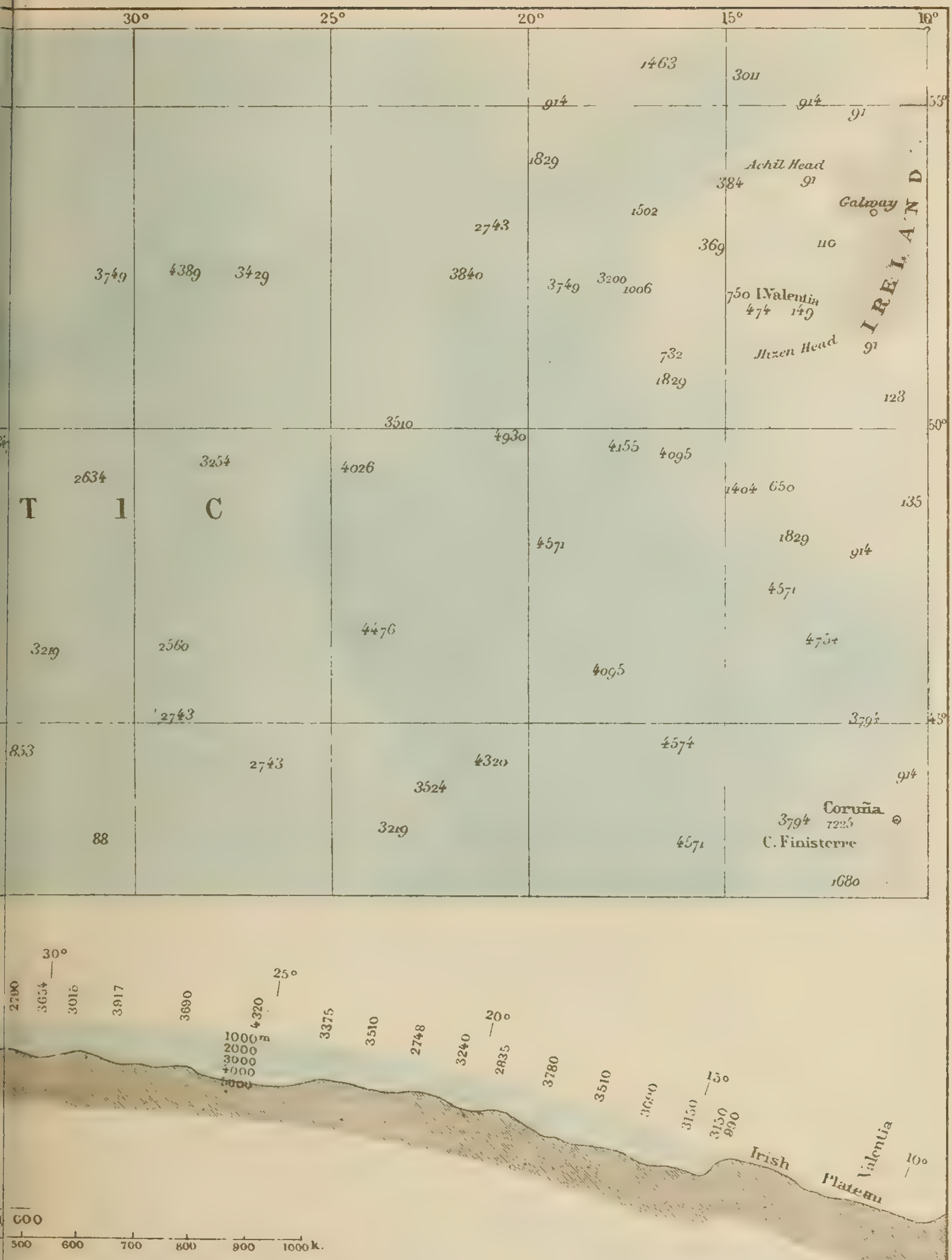
PL III.



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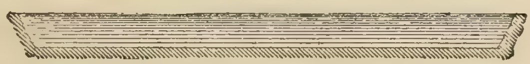
prodigious abyss has been discovered, called "the Great Swatch," which is no less than 2187 fathoms deep, and is bounded on the north, east, and west by deposits of mud and ooze, which the lead touches at some 5 or 10 fathoms. The formation of this singular funnel is perhaps due to an eddy of tidal waters, commencing precisely at that spot where the alluvium of the Ganges is brought down to mingle with the sea.

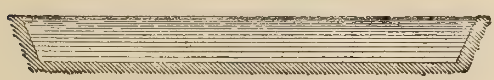
Almost all the Indian Archipelago, Sumatra, Java, Borneo, and the adjacent islands, rest on a submarine bank, having on an average only a depth of 33 fathoms, and even at the deepest places only 55 fathoms. This is probably the base of an ancient continent, of which the innumerable islands scattered over the sea in these latitudes are the remains. Another bank, extending for 435 miles to the north and north-west of Australia, supports that continent, and all the neighbouring islands, including New Guinea. A channel of very deep water, not yet sounded,

Fig. 8.—Depths of the Pacific Ocean shown by the Velocity of Earthquake Waves.

Scale of heights: 200 times that of lengths.



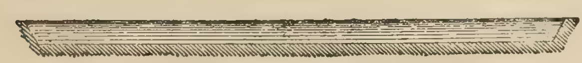
a. From Arica to Samoa.



b. From Arica to the Sandwich Islands.

c. From Arica to Chatham Island.

d. From Arica to Newcastle.



e. From Arica to New Zealand.

separates from the Asiatic archipelago those higher Australian levels, which also seem to be only the ancient fragments of vanished land. It is around these two great continental basements that the Pacific and the Indian Oceans, properly so called, commence.

With respect to Antarctic latitudes, 1722 fathoms have been found between the 63rd and 64th degrees; near the 78th degree, at the very side of the enormous barrier of ice which hinders any advance towards the pole, Sir James Ross has touched the bottom at 415, and the *Challenger* at 2000 fathoms. And this is all the information which navigators have hitherto given us. The icy sea of the north is better known, at least in some parts. To the north of Siberia, the bed of the sea, continuing the slope of the hardly-inclined "tundras," extends towards the pole with such a slight declivity, that at 156 miles from the coast the lead only shows a mean of from 14 to 15 fathoms. North of Spitzbergen, which is connected by a submarine bank with Europe, the German Polar expedition

recorded 2,650 fathoms. More to the west, between Scotland and Iceland, the parts explored by McClintock, with the view of laying the telegraphic cable, are rarely more than 328 fathoms, and nowhere present a depth of water of more than 670 fathoms. Between Iceland and Greenland a depth of 1547 fathoms has been sounded, and in Baffin's Straits are abysses of nearly 2000 fathoms. This great depression makes Greenland a country quite distinct from the American continent. The plateau upon which this grand island rests presents slopes relatively very steep. On the western side the declivity is in certain places one yard for every five of distance, while the western slopes of the submarine plateau of Ireland, which are among the most rapid in all the ocean, have about one yard of fall for every eight yards of length.

We can see clearly that the state of our knowledge of the subterranean surface is still very limited; yet the sum of the facts which have been already scientifically confirmed gives a great probability to the opinion, very natural on other grounds,

Fig 9.—Depths of the Sea at the Mouth of the Ganges.

that the oceans deepen gradually towards the south, where the waters occupy the greatest extent on our planet. The celebrated chemist and geologist, Bischof, thinks we may conclude from the comparison of all the soundings, that the bottom of the sea is on an average as near the centre of the globe as the poles themselves. In certain latitudes, and notably towards the 78th degree north, the terrestrial radius drawn to the bottom of the sea is even less than that at the pole, which perhaps is to be attributed to the wearing away of the soil by icebergs. But, on the other hand, in the greater part of the ocean the bottom of the sea is a little more distant from the centre than the poles, which doubtless arises from the alluvium brought down by the rivers and the accumulations of organic remains. Thus the part of the globe covered by the seas might be considered as perfectly round, and Newton's hypothesis, explaining the bulging at the equator by the state of fluidity in which the planetary mass had originally been, would become unnecessary.

As to the mean depth of the whole mass of the marine waters, we can hardly

estimate it at less than from 2 to $2\frac{1}{2}$ miles; since, as we have already seen, the entire basin of the Atlantic, and that of the Northern Pacific, which border upon the great northern continents, are deeper by many hundreds or even thousands of fathoms. Otto Krümmel was the first to discuss all the bathymetric data, and calculate the area and volume of the various oceanic basins, in order thus to determine an approximate average. According to this writer, the mean depth of all the great seas, gulfs, and inlets is as under :—

OCEANS.

Atlantic	2040 fathoms.
Indian	1856 ,,
Pacific	2160 ,,
Antarctic	1800 (?) ,,
Arctic	860 ,,

INLAND SEAS.

Mediterranean	760 fathoms.
Baltic	37 ,,
Red Sea	246 ,,
Persian Gulf	21 ,,
Australian	490 ,,
American	1000 (?) ,,

GULFS AND INLETS.

North Sea	50 fathoms.
English and St. George's Channel	47 ,,
Gulf of St. Lawrence	160 ,,
China Sea	67 ,,
Sea of Japan	1220 ,,
Sea of Okhotsk	840 ,,
Sea of Behring	550 ,,

Taking as the total surface of the ocean, an extent of more than 150 millions of square miles, we find that the sea forms a volume of about $2\frac{3}{4}$ million billions of cubic yards, that is to say, the 560th part of the planet itself. Sir John Herschel gives much higher figures for the same volume of water; but he has taken, as the basis of his calculation, the probable maximum of the depth of the seas, that is to say, four English miles, more than 3738 fathoms. We cannot speak yet with certainty, but one day, thanks to the new observations which are added every year to those which science already possesses, it will be possible to give figures more relatively exact for the depth of the marine abysses, and the mass of water that fills them. One thing is certain, that the highest part of the continent raised above the surface of the waters is of much less elevation than the depth of the sea; and we can estimate the land above the level of the sea at only about a fortieth part of the mass of waters. Besides which, the land itself contains within it an enormous quantity of water united either chemically or mechanically with all rocks. The land itself is exactly $2\frac{1}{2}$ times less extensive than the main basins; but its weight being $2\frac{1}{2}$ times greater, it follows that both are exactly balanced. But whether this fact, discovered by Krümmel, is a mere

coincidence, or the expression of a law in the evolution of the planet, can be determined only by more exhaustive studies.

The water of the seas, urged by the force of gravitation, constantly seeks its level, like the water of rivers and lakes. When, in consequence of very rapid evaporation, or of a succession of tempests blowing from the same quarter of the horizon, the surface of the sea is lowered in any gulf, the waters from the adjacent parts rush towards the impoverished space to fill the void. In the same way, when great rains, the swelling of large rivers, or the action of winds have raised the level of the sea in one point, this local swelling soon subsides, and its superfluity is dispersed over the surrounding surfaces. We may, therefore, consider the mean height of the sea as the same in every ocean, since the natural movement of water tends ever to re-establish an equality of surface in all parts where an accidental disturbance has occurred.

Nevertheless, the diversity of climates, of winds, and of currents, is such, that certain seas, separated from one another by a narrow isthmus, present permanently unequal levels. Thus several German engineers believe that they have established the fact that the Baltic Sea, into which a great number of considerable rivers discharge themselves, is on an average some inches higher (?) than the North Sea. In the same manner the Atlantic, whose waters spread out on one side into the North Sea, and on the other into the Mediterranean, would have a mean level scarcely higher than that of the two basins which it supplies; while the Black Sea and the Gulf of Venice, receiving, like the Baltic, several large rivers, would, like the latter, be proportionably elevated. On the two sides of the Isthmus of Suez the waters are also found at slightly unequal heights. According to the engineer Bourdaloue, the mean level of the Red Sea at Suez exceeds by $31\frac{1}{2}$ inches that of the Mediterranean near Port Saïd; at low tide the two sheets of water are perceptibly of the same level, while at high-water the sea is sometimes higher by $3\frac{1}{4}$ feet in the Bay of Suez than at the northern extremity of the maritime canal A similar difference, too, occurs between the Bay of Colon and the Gulf of Panama, and there also it is the mass of water in which the tides have the fullest swell, that is to say, the Pacific Ocean, which has the highest level. But the measurements made on the always unstable level of the sea are very delicate operations, as one can so easily make a mistake at starting, through the oscillations of the ebb and flow; and over spaces of many miles, divided by various obstacles, it is very difficult to avoid slight errors. At all events, it is certain that the surface of the sea, unceasingly traversed and perturbed by winds, currents, and tides, is not perfectly horizontal at any point of the globe. On the French seaboard facing the Atlantic Ocean the mean height of the tides varies in every port. According to M. Bourdaloue, the difference between Havre and Port Launay in Brittany is about 40 inches.

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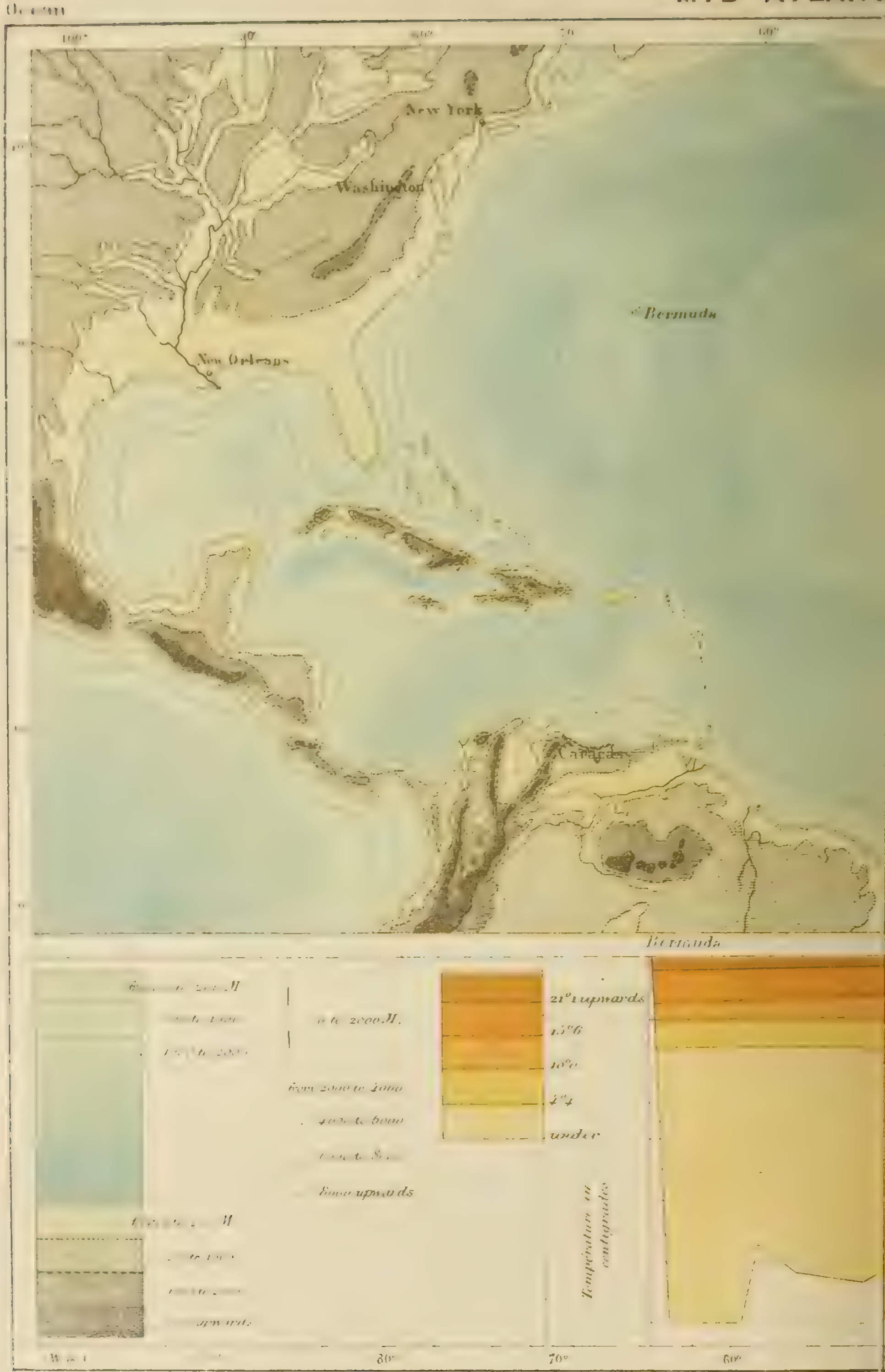

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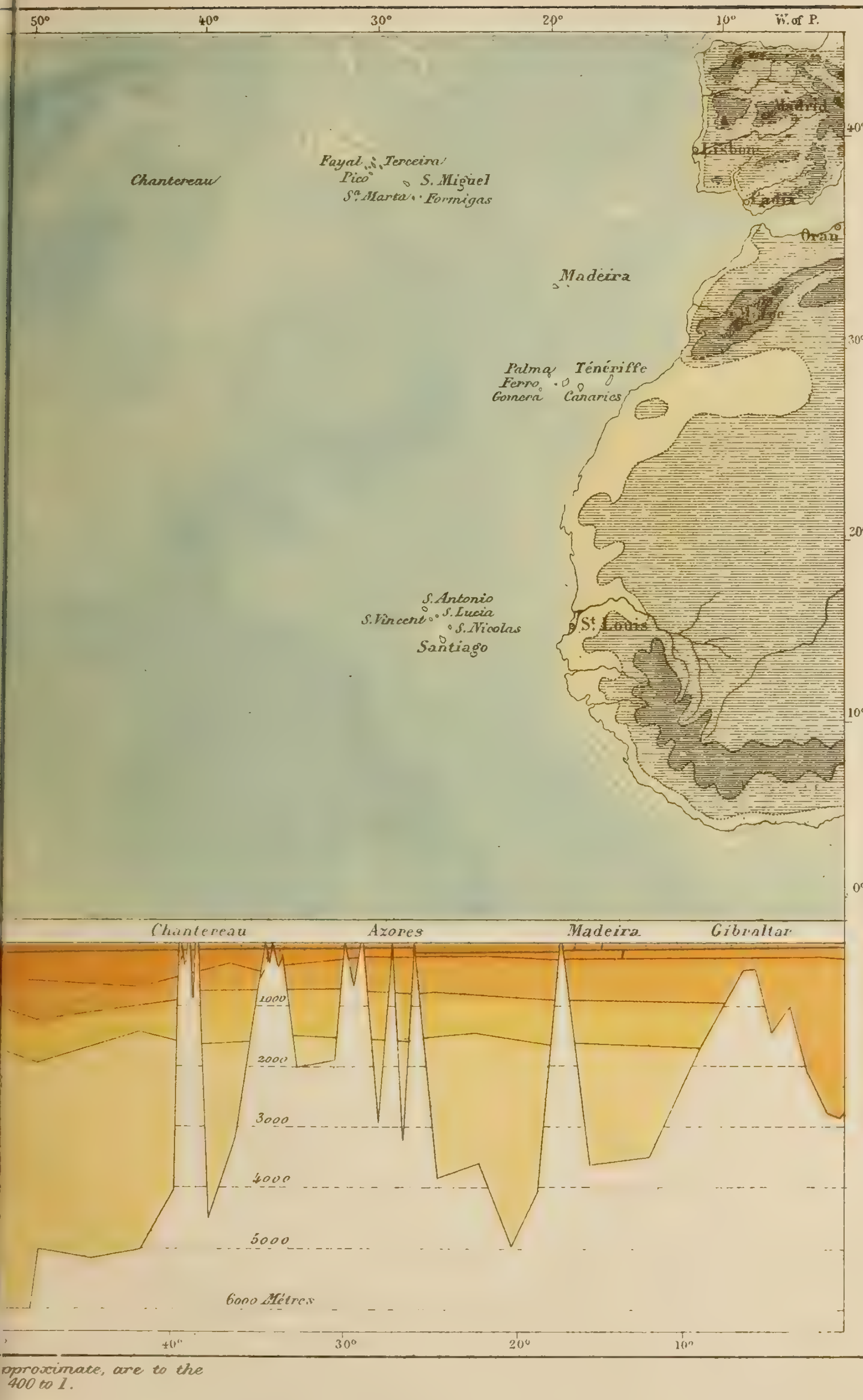

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CHAPTER III.

COMPOSITION OF SEA WATER.—SPECIFIC WEIGHT.—SALT MARSHES, NATURAL AND ARTIFICIAL.—VARIOUS SUBSTANCES.—DIFFERENCES OF SALTNESS.—MARINE SALT.

BESIDES the ooze, the remains of animalculæ, and innumerable fragments held in suspension, the sea water is also charged with chemical substances in solution, which give it a specific gravity considerably superior to that of fresh water. This varies in all seas, according to the quantity of the substances dissolved, the amount of evaporation, the contributions of rain and rivers, the direction of the currents and counter-currents. In the polar seas the specific gravity of the waters is also modified by the formation, or melting, of the ice. Every variation of temperature, every local movement of the sea, causes a more or less perceptible modification in the proportion of the salts dissolved, and in the specific gravity of the water. Thus we can only obtain an average for the various conditions of the fluid mass in the different seas.

The mean specific gravity of oceans with deep basins is nearly 1028; that is to say, sea water weighs 2·8 per cent. more than the same bulk of distilled water. In the Mediterranean, where the heat of the sun evaporates more water than the rivers bring down to it, the average specific gravity exceeds 1029; in the Black Sea, on the other hand, where very considerable rivers of fresh water discharge themselves, the specific gravity is reduced to 1016. And all the intermediate degrees between these extreme specific gravities are found, according to the varied physical conditions which exist, in other seas. Furthermore, it seems to be established that the waters of the ocean in the southern hemisphere are, on an average, lighter than those of the northern hemisphere.

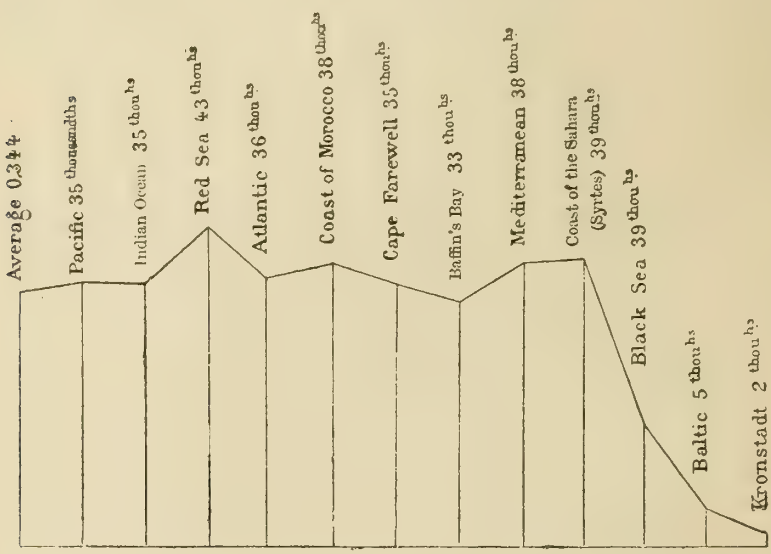
The average quantity of all the salts contained in the sea, or the saltness of sea water, was estimated by Bibra and Bischof at 35·27 parts in 1000; but much more complete observations made since by Forchhammer have reduced this proportion to 34·40. Besides, almost all the analyses, which up to the present time have been made of sea-water, confirm the general opinion of chemists, that the relative proportion of the matters dissolved is the same in all seas. The quantity of common salt (chloride of sodium) dissolved in sea water is always a little more than three-quarters (75·786) of the total mineral matter held in solution.

In the North tropical Atlantic, on the coasts of the Sahara and of Morocco, where the sea receives no tributaries, and where, on the other hand, the evaporation is very rapid, the average of oceanic salts is nearly 38 parts in 1000. In mid-ocean, and more especially in the neighbourhood of America, where the water of many

great rivers mingles with that of the sea, the saltness is less by one, two, and even three thousandths; but it is generally greater in the tepid waters of the great current called the Gulf-stream, which crosses the Atlantic obliquely. The proportion of salts contained in this current always exceeds 35 thousandths, while the water that flows from the pole towards the equator by Baffin's Bay, contains only about 33 thousandths. It is to the enormous accumulation of ice, that these currents owe the slightly less saltness of their waters. The quantity of cold water which flows from the Antarctic Pole towards the south of Africa and America, contains likewise less saline matter than the seas of the temperate and equatorial zones.

With regard to basins almost enclosed, like the Mediterranean, the Caribbean Sea, and the Baltic, the saltness ought evidently to be greater or less there than in the ocean, according as the evaporation is in excess of or is inferior to the fresh water brought by the rivers and the clouds. In the Mediterranean, the loss in

Fig. 10.—Comparative Saltness of Seas.



evaporation being more considerable than the contributions of fresh water, the saltness ought to increase in consequence, and the liquid mass would constantly diminish, if a current setting in from the Atlantic through the Straits of Gibraltar did not restore the equilibrium. While the less saline waters of the ocean thus penetrate into the Mediterranean, flowing along its surface, a submarine counter-current, composed of heavier and salter water, flows deep below in an opposite direction, and mingles with the waters of the Atlantic, which contain less salt. The mean saltness of the Mediterranean is nearly 38 thousandths, and even exceeds 39 thousandths on the coasts of Tripoli, where the parching winds of the Libyan desert blow.

In like manner the Caribbean Sea seems to present a somewhat high relative saltness because of an excess of evaporation over the contribution of fresh water; but the contrary happens in the Gulf of St. Lawrence, in the North Sea, and above all in the Baltic and the Euxine. The saltness of the North Sea is in different parts from 30 to 35 thousandths, while that of the Baltic, a shallow sea into which

so many rivers flow, and where the least wind disturbs the waters, does not quite amount to five thousandths; in the port of Kronstadt it is not even two-thirds of a thousandth, which is almost fresh water. As to the Black Sea, it preserves, even more than the Baltic, the character of a gulf of the ocean, for the average saltness is about half that of the Atlantic.

These differences of salinity, between the central basin of the Atlantic and its tributary seas, are not in themselves astonishing; but we do not yet know why the South Sea and Indian Ocean contain less saline matter in their waters than the Atlantic, unless the enormous quantity of Antarctic ice explains this difference. While the latter has a saltness of about 36 thousandths, the water of the Pacific has less by nearly one thousandth, and the Indian Ocean contains no more than 35 thousandths of chemical substances. The Atlantic, however, receives a greater quantity of fresh water than the other oceans, and the evaporation is probably not so great on an average as in the Indian Ocean. But, nevertheless, the gulfs of the Indian Ocean present phenomena analogous to those of the inland seas of the Atlantic. Thus the Red Sea, into which no single permanent stream of water flows, and where evaporation proceeds with very great intensity, shows the enormous degree of saltness of 43 thousandths—such a proportion as is only found in inland salt-water lakes.

Chloride of sodium, or common salt, contributes, as we have said, three-quarters of the saltness of sea water: this is indeed the characteristic salt of the ocean which most of all gives it its peculiar flavour, and that odour with which the sea-breezes, laden with the fine spray of the waves, are charged. The air which rests on the sea also contains salt to a considerable height; at an elevation of 2,000 feet above the coast on the sides of the mountain which towers above the Peruvian town of Iquique, Mr. Bollaert asserts that any materials washed in distilled water are covered in a few days by a slight incrustation of salt.

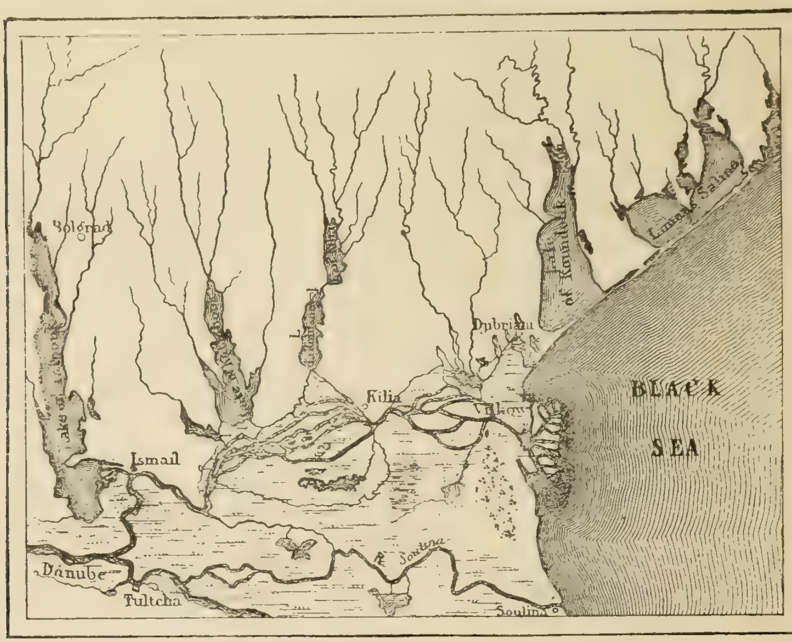
The thickness which a layer of chloride of sodium in the open sea would form if crystallized, would be on an average nearly two inches to every fathom of water, so that if one could imagine the entire evaporation of the waters of the ocean, estimating them to be on the average above three miles deep, there would remain at the bottom of its bed a layer of salt of about 230 feet in mean thickness, which would represent for the whole extent of the seas more than a thousand millions of cubic miles. We can understand how, with such vast quantities of chloride of sodium in solution, the sea has been sufficient to form those enormous beds of rock-salt that are found in the earth in various parts of Europe, without reckoning many other deposits which still remain to be discovered, and which, sooner or later, will be revealed to us by the labours of miners, or by artesian borings.

The ocean may also be seen at work on all the low coasts, where it deposits saline beds, destined to become in process of time masses of rock-salt, after they shall have been buried beneath more modern strata. When, in consequence of a tempest, or of a high tide, the waters of the ocean are spread in a thin sheet over a flat shore, or in some deeper depression, this slight bed of salt water, spread over a vast surface, evaporates rapidly under the rays of the sun, and leaves in its place a slight white crust of saline crystals. Other sheets of water, urged by the billows or the tide into the same basin of evaporation, disappear likewise, forming new layers of crystals; it is thus that real banks of a considerable thickness are gradually formed on the borders of the sea, as well as on the shores of inland seas and salt lakes.

Even the Black Sea, where the proportion of salt is relatively very inconsider-

able, is, on the greater part of its shores, bordered with these natural salt marshes. In Bessarabia, to the south of Odessa, three "limans" of a total area of many square miles, cease in summer to receive their affluents of fresh water, and all the water which has been brought there in winter evaporates, leaving an incrustation of salt; towards the centre of the basins of crystallization the solid mass attains nearly an inch in thickness. In 1826, these natural deposits, worked by the natives, produced about 120 thousand tons of pure salt. In most of the populous countries of Western Europe, man has converted these casual swamps into salt marshes with regular outlines. The unequal depressions, where the water of the sea evaporated accidentally, are transformed into reservoirs, where the water is conducted from compartment to compartment, to saturate itself gradually and

Fig. 11.—Salt Marshes of Bessarabia.



deposit the pure salt in equal layers. But these are only economical works; man is confined to regulating the operations of the sea itself.

Besides common salt, many substances which are exceptionally found in inland waters and hot springs, form a part of the normal composition of sea water. The various simple substances which science has been able to discover therein (either directly by the analysis of the liquid, or indirectly by the study of the plants which draw all their nourishment from the ocean) are twenty-eight in number; but doubtless numerous other simple substances are likewise contained in sea water, many of which will not long escape the piercing researches of chemists.

After oxygen and hydrogen, which constitute the liquid mass itself, the principal elements contained in sea water are: chlorine, nitrogen, carbon, bromine, iodine, fluorine, sulphur, phosphorus, silicon, sodium, potassium, boron (?), aluminium, magnesium, calcium, strontium, barium. The common fucus and other sea-weeds contain the greater part of these substances, as well as several metals. Copper, lead, and zinc have been discovered in the ashes of *Fucus vesiculosus;* cobalt, nickel, and manganese in those of the *Zostera marina.* Iron may be obtained

directly by an analysis of sea water, and finally silver is found in a zoophyte, the *Pocillopora*. Forchhammer has obtained from a branch of this coral about a three millionth of silver, mixed with six times the same quantity of copper, and eight times of lead. A slight proportion of silver is precipitated on the bottoms of ships, in consequence of the magnetic current established between the copper-sheathing and the water of the surrounding sea. And lastly, arsenic has been found in the boilers of steamers which have been supplied with sea-water. It is true that these various substances only exist in infinitesimal proportions in the water, and it is by indirect means alone that chemistry succeeds in revealing them; but the total mass of silver contained in the ocean is estimated at two millions of tons.

The seas having most probably received from the terrestrial strata, which have been unceasingly worn away by the currents of water, all the substances which they contain in solution, we may conclude that the proportions of these substances have continually varied during the geological eras. The saltness would be modified from age to age, according to the various quantities of soluble substances which the rivers brought down to the ocean, and which it returned again to the land, either directly, by depositing them on the shore, or indirectly, by fixing them in the tissues of the plants, corals, and other organisms which people its expanses. By ingenious comparisons between the conditions of the present day and those which seem to have existed in former times in the sedimentary beds, several geologists have attempted to determine if the substances in solution in sea water have augmented or diminished. But the conclusions at which they have arrived rest, at present, on data too hypothetical for us to regard them as a new conquest of science. It is only certain that in our day the proportions of the substances dissolved have not ceased to vary in every sea. We can judge of this by the enormous difference that there is between the saltness of the waters of the Caspian and those of the Black Sea, two separate basins which formed a part of the same ocean at a geological epoch still comparatively recent.

Sea water contains also a great quantity of the atmospheric gases, the proportions of which constantly change with heat, light, the motion of the waves, and barometric pressure. Salt water retains dissolved air better than fresh water, and the bulk which it absorbs is generally greater by a third than that found in rivers. It varies from a fifth to a thirtieth, and gradually increases from the surface to a depth of about 325 to 380 fathoms. Carbonic acid gas is also contained in a relatively very considerable proportion in sea water, as might have been expected from the swarming myriads of marine animals. Under the influence of light, plants decompose this gas, which diminishes during the day and is increased again during the night. As to the quantity of dissolved oxygen, it varies inversely; during the day it increases by degrees, to be again reduced in the hours of darkness. As by a sort of respiration the great sea, that immensity alive with organisms, absorbs and disengages alternately the gases necessary to the maintenance of life, and measures each breath by the daily course of the sun.

The whole subject of the salinity and general constitution of the marine waters is thus summed up by Mr. John Murray:—

"The moisture taken up from the sea by the winds, leaving the water salter than before, is borne to the land and condensed on the mountain slopes. Eventually this water gathers off the land, passes by rivulet, stream, and river down again to the ocean, bearing along with it a burden of earthy matters in solution. In this manner the ocean has most probably became salt in the course of ages. The water of the ocean now contains, it is almost certain, a portion of every element in

solution. Many of these are present in exceedingly minute traces. They are detected either in the sea water, or the evaporated-down residue by spectrum analysis; in the copper of ships' bottoms, which have withdrawn them by chemical decomposition; or again in the ashes of sea-weeds and marine animals, which during life exert a selective influence upon the surrounding water."

The individual salts present in sea water are, of course, constantly interchanging their metals and acid radicals, so that it is impossible to say authoritatively what is the precise amount of the respective chlorides and sulphates of sodium, potassium, calcium, and magnesium actually present. But it has been shown by hundreds of laborious and most delicate experiments that the actual ratio of acids and bases in sea salts—that is, the ratio of the constituents of sea salt—is *constant* in waters from all depths, with one very significant exception, that of lime, which is present in slightly greater proportion in deep water.

The total amount of dissolved salts in the ocean would, it is calculated, if extracted, form a pavement 170 feet thick over the entire bed of the ocean, and of this amount $1\frac{1}{4}$ inch would be composed of pure carbon, chiefly present as carbonic acid in the carbonates.

On account of the constancy of its composition, the determination of any one of the constituents of sea salt—chlorine, for instance—gives the datum for calculating the salinity—that is, the proportion of total salts to the water in which they are dissolved; though determinations of this nature are more conveniently made by observations of density by means of the hydrometer. Mr Buchanan's laborious investigations show that the surface water of the ocean is freshest—that is, contains the least salt—at the poles and in the equatorial belt of calms. In the east of the Indian Ocean a change of the monsoons brings about a great change in the salinity of the surface water. The centres of the great systems of oceanic currents produced by the trade winds, are the areas of highest salinity in the open ocean; yet here the water is not so salt as in the enclosed seas situated in areas of great evaporation, as the Mediterranean, and especially the Red Sea and Persian Gulf, where the saltest water is found, and where a regular circulation is kept up by the outward flow of the denser water. The salinity of the deeper waters is considerably below the average at the surface in the open ocean, especially in the Atlantic.

CHAPTER IV.

VARIOUS COLOURS OF SEA WATER.—REFLECTIONS, TRANSPARENCY, AND PROPER COLOUR.—TEMPERATURE OF THE DEPTHS OF THE SEA.

OWING to the double property which water possesses of reflecting light and allowing its rays to penetrate to a great depth, it presents successively the most varied colours, the most delicate tints, with alternations the most fugitive and changeable that are to be found in nature. The sea produces and at the same time modifies the varied face of the heavens with all the play and gradation of light and shade. At dawn, the surface of the water is gently brightened by the glimmering of the atmosphere as yet pale and faint; then the sparkling of the waves becomes more brilliant, and the full light of day pours a flood of fire upon the billows. The least movement in the air is betrayed by a change in the aspect of the water, every cloud in passing mirrors itself with the forms and shades of its vapours, every breath of wind that just curls the waves renews the harmony of the changeable colouring on the face of the ocean. And when evening comes, the sea reflects back to the sky all its splendour of purple and flame. It is then that we see on the horizon, "two suns appear, one in front of the other."

But the water does not owe its beauty to the splendour of the sky alone, it is beautiful also from its transparency; whilst the substances suspended in the liquid mass, which are visible to a considerable depth, modify by their own colour the general tint of the sea. The animals, fish or cetaceans, which come to the surface or glide swiftly through the waves, cause them suddenly to glitter with changing reflections of grey, rose, green, and silver. The fuci, too, growing beneath the water, vary the aspect of the liquid strata which cover them, and where these beds of plants alternate with ridges of bare rock, or tracts of sand, the sea presents a wonderful mixture of different shades with blended and tremulous outlines. In those latitudes where the water is very transparent, the colour of the ground may be thus distinctly seen at 10, 20, or even 25 fathoms below the surface, which navigators have confirmed by scientific observations made with the greatest care. But this transparency does not seem to depend upon the intensity of light received, for in the Arctic Seas floating objects can be perceived at as great depths as in the Caribbean Sea; and it is indeed in polar latitudes that the eye of man has been able to penetrate to the greatest depth below the surface. According to Scoresby, that conscientious explorer of the polar seas, the sea-bed of the pure waters in these regions is sometimes visible at a depth of 70 fathoms. It is true that, in consequence of climatic differences and the organic life which depends on them, the bottom of the sea is much more curious to contemplate in the tropical zone than in

the neighbourhood of the poles. There is nothing more delightful than to sail over one of those seas where, without fear of hidden rocks, one can watch the bed of the sea reveal itself far below the prow of the vessel. Numerous algæ, green or rose-coloured, wave gracefully below the surface like the grasses of a brook; the molluscs crawl along the bottom; crustaceans, fish, star-fishes of brilliant colours and many other animals of strange form, glide slowly or dart like arrows through the blue water, glistening in a thousand changing hues; while the Nemertida and other living ribbons softly unroll their transparent rings. One might fancy oneself suspended above another earth, and floating in an aërial ship. The white foam on the waves raised by the ship's keel, and the iridescent colours which sparkle in the spray, add fresh charms to this wonderful picture.

Even when the bed of the sea is not distinctly visible, it does not fail to reveal itself by the peculiar tint it imparts to the water. In general the colour of the sea is lighter near the coasts, and even at a depth of above 100 to 150 fathoms, a paler shade of the water at times makes known to the practised eye of the mariner the relative proximity of the bottom. Not far from the coasts of Peru, de Tessan perceived that the sea had suddenly assumed a tint of dark olive-green, and when he caused a sounding to be taken, it was found that the mud at the bottom was precisely of this colour. Numerous navigators have affirmed that in one part of the Lagullas bank, where the mass of water is above 100 fathoms deep, the water passes suddenly from blue to a greenish colour. Lastly, off Loango, the water is always brown, similar to that of the bottom, which Tuckey has found to be of an intense red. Is, then, this colouring owing to the sun's light, which descends through the liquid depths to the bed of the sea, and is reflected again to the surface; or does it result, as Cialdi thinks, from particles of mud that are floating in the water?

Another question, difficult to solve, is that of knowing what is the natural colour of the sea water. Not to mention local colouring, resulting like phosphorescence from numberless minute living organisms, the various parts of the ocean almost always present, whatever may be the state of the atmosphere, a normal tint easy to be distinguished from accidental shades. Thus, to cite one of the most striking contrasts, the water of the Bay of Biscay is of a sombre green, while in the Gulf of Lyons the water of the Mediterranean is of a magnificent azure, deeper than that of the sky. The wonderful blue colour which rises from the depths of the water in the Grotto of Capri, so frequently visited by travellers, is a well-known example of the degree of intensity to which the blue peculiar to the waters of the Mediterranean can attain. In the tropical latitudes of the Atlantic and the South Sea, the azure of the ocean is no less beautiful than that of the Tyrrhenian Sea; while in the direction of the poles the water gradually assumes a greenish tint. Naturalists have concluded from this fact that the refraction of the rays of light, which are much more vivid under tropical latitudes, play a principal part in the blue colouring of the sea. Maury thinks that the saltness is also one of the causes which contributes the most to give its azure tint to the water; and observes that the Gulf-stream of the American coasts, superior in salinity and in temperature to the water around it, is also of a much deeper blue. In the same way the shallow water let into the salt marshes of coasts, gains in intensity of colour in proportion as the salt is concentrated there. Still it is very possible that the colouring of the sea is due in great part, like the marvellous tints of the Swiss lakes, to innumerable corpuscules held in suspension, upon which the light strikes.

When we pass to a consideration of the water of the ocean, which fills the great hollows of the earth, it is essential to take account of the superincumbent atmospheric ocean, which everywhere rests on its surface, for the composition of the ocean water, the currents, the distribution of salinity, density, temperature, and even that of deep-sea deposits, are largely determined by the movements of the atmosphere.

One of the most important parts played by the ocean in the economy of the globe is to bring about a more equable distribution of temperature by the winds which blow from it over the land and by means of the oceanic currents that are originated and maintained by the winds.

From the smallness of the *daily* variations on the temperature on the surface of the sea, which are shown by the *Challenger* observations, as discussed by Mr. Buchan, not to exceed 1° F., as compared with the large daily variation on land, there result directly the land and sea breezes with all their beneficial consequences. Similarly, from the small *yearly* variation of the temperature of the sea, as compared with the very large variation of the temperature of the land surfaces of the globe, result those great annual changes of the prevailing winds—the most important of which, with respect to widespread climatic effects, is the summer monsoon of the Europeo-Asiatic continent.

But the most important, as well as the most direct, effect of the unequal distribution of temperature over the surfaces of the oceans and continents, is an unequal distribution of atmospheric pressure varying more or less with the season. On the one hand, in a particular season we see a portion of the earth's surface with atmospheric pressure much less than in surrounding regions, and as long as the low pressure is maintained the winds from the regions all around continue to blow inwards upon it, bearing with them the temperatures and humidities of the regions from which they have come. On the other hand there are other parts of the earth's surface with atmospheric pressure much higher than in adjoining regions, and, as this state of things continues with little variation throughout the year, the winds blow out in all directions towards surrounding regions. Of this two illustrations may be given.

During winter months atmospheric pressure is much less in the North Atlantic about Iceland than it is all round, and towards this area of low pressure the winds from the surrounding continents blow vorticosely, thus determining the winter climates of the more important countries of the world. Over Canada and the United States the winds are north and north-westerly, by which the rigours of winter are intensified; but in Western Europe the prevailing winds are south-westerly, and, as these winds bring with them the warmth and moisture of the Atlantic, the winter climates of Western Europe contrast strongly, latitude for latitude, with those of the eastern states of America.

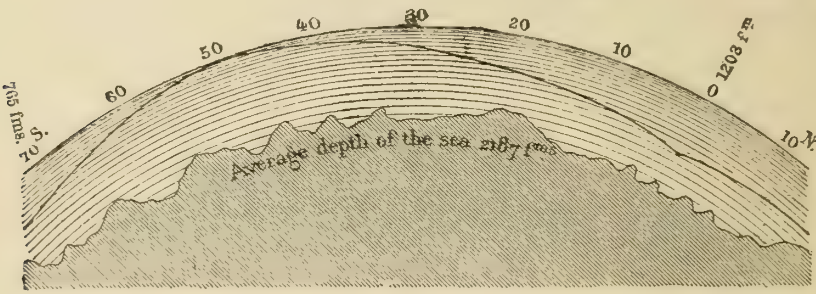
Again, pressure is higher in the Atlantic between the north of Africa and America than it is all round, and out of this anticyclonic area of high pressure observations show that the winds blow in all directions towards surrounding regions where pressure is less. To the westward of North Africa the prevailing winds are northerly and north-westerly, but on the south side of this anticyclonic region the winds are easterly, and on the west the winds are southerly.

Owing to these very different winds, and the oceanic currents to which they give rise, the temperature of the sea is much higher off the coasts of Florida than it is off the coasts of Africa in the same latitudes. The effect of these differences is recognisable in the distribution of marine life and coral reefs, and, consequently, of the deposits at the bottom of the sea.

The law of the distribution of temperature, in the depth of the ocean, is not as yet more determined than that of the colouring of the water. At the surface of the sea it is as easy to make observations as in the air, and it has been determined, without difficulty, that this superficial sheet of water presents on an average, in all climates, the same degree of heat as the superincumbent atmosphere. Thus, from the polar regions to the equatorial zone, the water becomes warmer with an almost regular gradation, and, from the freezing-point under the Arctic circle, the temperature rises to 68° and 77° F. under the tropics, and to 86° and even above 90° F. in the Pacific, the Red Sea, and the Indian Ocean. With regard to the increase or decrease of heat in a vertical direction, we had till recently only the vaguest notions, in consequence of the want of exact soundings. It is in fact very difficult to lower to a depth of several hundred, and even several thousand fathoms, thermometrical apparatus strong enough to resist the enormous pressure of one atmosphere for every 33 feet.

Sir James Ross was one of the first who attempted to apply the resources of modern science to a systematic exploration of the temperature in the depths of the sea; but he seems to have committed the error of generalizing too hastily from the incomplete results which he obtained; and in his eagerness, he believed he had discovered a law, which the subsequent researches of navigators have not confirmed.

Fig. 12.—Sheet of Water presumed to be at a Temperature of 39·2 Fahr.



He thought that he could establish the fact that under the equator the temperature of the water diminishes gradually to 1200 fathoms, where it is only 39·2° F.. On each side of the equator the upper waters gradually cool, and the limit of four degrees is progressively raised towards the surface; it is at the fiftieth degree of latitude, in the southern hemisphere, that it finally reaches the level of the sea. Farther in the direction of the pole the superficial water continues to grow colder, while the line of four degrees sinks gradually to the depth of 765 fathoms. Thus, as the accompanying figure shows, the line of uniform temperature to the south of the equator describes a long curve, touching the surface of the water at one point only. Admitting with the naturalists of his time, that the sea water has its greatest density, and in consequence its greatest relative weight, at seven degrees above freezing-point, Sir James Ross concluded from this that all the deep waters below this line of 39·2° have the same temperature, and are collected by reason of their condensation at the bottom of the oceanic basins.

Nevertheless it has since been proved, by the observations of Neumann and other scientific men, that if the greatest density of fresh water corresponds in reality to 39·2° F., the water of the sea only attains this maximum at nearly four degrees below freezing-point (28·4 F.), or even at still lower temperatures, and, in consequence, the conclusions at which Sir James Ross arrived are negatived.

Experiments made in chemical laboratories, however, where substances are treated in small quantities, cannot give a perfectly exact notion of the phenomena which have nature itself for their theatre, and which take place either in the aërial spaces or in the vast oceanic basins. Thus, as the celebrated meteorologist Mühry says, the immense sea, and a bucketful of salt water, do not obey absolutely the same laws of temperature and density. But before the difference is established, nothing can authorize us in maintaining a superannuated theory against all the experiments of chemists, according to which the volume of salt water in the sea in cooling presents phenomena identical with those of fresh-water lakes. Moreover, during the past years numerous observers of polar seas have found at great depths, beds of water at a temperature lower than 39·5° F.

That which remains of the researches of the eminent navigator, Sir James Ross, is that in the tropical and temperate seas the heat diminishes gradually and constantly to a considerable depth. This is what has been put beyond all question, by soundings taken by Fitzroy and other marine explorers. To the south of the island of Madagascar, the surface of the water having then a temperature of 75·2° F., Fitzroy ascertained that the thermometer fell in the most regular manner, till at the depth of 420 fathoms, where they ceased sounding, the temperature indicated hardly exceeded 51·8° F.

Below the surface, the thermometer traversing the liquid layers indicates a rapidly decreasing temperature; but according as it sinks deeper and deeper the column of mercury falls continually slower. At the bottom of the polar seas the water has usually a temperature of from 32° to 38° F. Under the temperate latitudes of the northern hemisphere the warmth of the deep waters oscillates between 34° and 40° F., but is lower under the corresponding latitudes of the Antarctic regions. Lastly under the equator the cold waters brought by the two opposite polar streams, which here meet and arrest each other's progress, penetrate to a relatively great depth. Thus it happens, by a remarkable and at first sight almost inexplicable contrast, that the deep waters of the equatorial basin are colder than those of the temperate seas.

All irregularities in the disposition of the temperatures in the liquid mass bespeak a constant submarine movement in the oceanic waters. Were the seas at rest, the heat, instead of decreasing from the surface downwards, would on the contrary progressively increase, in consequence of the natural heat of the rocks forming the bed of the marine basins. Bishop (" Internal Heat of the Earth," p. 3) has calculated that, were the equatorial waters undisturbed by any movements of opposing currents, they would reach the boiling-point at about a depth of 1200 fathoms below the surface.

In the enclosed basins of inland seas thermometrical observations are much more easily made than in the middle of the great ocean; because the waters there are generally less deep, and the natural gradations of temperature are less disturbed by currents. Thus the water is not very cold in the depths of the Mediterranean, and presents only slight variations of temperature. At about 100 to 275 fathoms below the surface, the fluid mass has already attained permanently the mean temperature, which it preserves during all the year, and which seems to correspond to the mean annual temperature of the neighbouring lands, which are subject to all the abrupt changes of heat and cold. While in summer the superficial sheet of water has about 73·4° F., the water comprised between 273 fathoms depth and the very bottom of the Mediterranean is found at 59° F., which is pretty nearly the mean annual warmth of the bordering countries. In the Greek Archipelago, the

deep waters of which are probably colder in consequence of the current flowing from the Black Sea, the waters of the surface have in summer from 77 to 78·8° F. and at hardly 98 fathoms depth the thermometer reveals a constant temperature of from 53·6° to 55·4° F. The Mediterranean is divided into distinct basins, separated from one another by intermediate ridges, which are situated from 98 to 273 fathoms below the surface, the result being that the variations of temperature produced by the movements of currents and counter-currents are arrested on the tops of the ridges. The water of each basin, being relatively tranquil, thus maintains almost constantly the same thermometrical degree.

In the equatorial regions, observes Mr. Murray, the surface water of the ocean has occasionally a temperature of 85° or 86° F., and the normal temperature in tropical and sub-tropical regions ranges from 60° to 80° F. This warm water is, however, a relatively thin stratum on the surface, the great mass of the ocean consisting of cold water—water of 45°, 40°, and of even a much lower temperature. At a little over half a mile of depth in the tropics the water has a temperature of 40°, and at the bottom it is still colder—ice-cold indeed. The ooze which is dredged from the bottom beneath the burning sun of the equator is so cold that the hand cannot be held in it for any time without great discomfort.

In the open ocean the temperature usually decreases with the depth, the coldest water being found at the bottom ; but sometimes there are limited areas where the temperature remains uniform for a mile or half a mile above the bottom. This has been shown to depend on the existence of barriers to free circulation, which exist on the floor of the ocean, and cause in a measure a resemblance to the conditions which are so marked in many partially enclosed seas, shut off by submarine barriers from general oceanic circulation, where the temperature is uniform, it may be, from a few fathoms below the surface to the bottom—for instance, in the Mediterranean and seas of the Malayan Archipelago.

The low temperature of deep ocean water was acquired at the surface in high latitudes, chiefly in the high latitudes of the southern hemisphere. The salt warm water of the tropical regions, which is driven in relatively rapid currents along the eastern shores of South America, Africa, and Australia by the action of the prevailing winds, on reaching a southern latitude of 50° or 55° sinks on being cooled, and spreads over the floor of the ocean. A similar circulation takes place in the northern hemisphere, though modified in many ways by the peculiar configuration of the land : for instance, it is almost certain that the cold water at a temperature of 30° F., which occupies the deeper part of the Norwegian Sea beyond the Wyville-Thomson Ridge, is the dense surface water of the Atlantic, which becomes cold and sinks as it passes northward in the extension of the Gulf Stream. Again, the relatively low temperature found on the eastern coasts of Africa and America seems largely due to the cold deep water which is drawn up to supply the place of the warm surface water driven forward by the trade winds.

CHAPTER V.

FORMATION OF ICE.—ICE-FLOES, FIELDS OF ICE, AND ICEBERGS.—ICE IN THE BALTIC AND THE BLACK SEA.—COLLISION WITH ICEBERGS IN A FOG.

IN the Polar seas the low temperature results in the formation of ice. During the long winters of these cold regions, the tranquil water of the bays and gulfs freezes round the edge of the coasts, and the crystallized mass gaining incessantly on the sea finally extends to a considerable distance. This is "ground-ice." The surface of the sea disappears like that of the lakes under a solid layer; but the manner of forming the icy crust differs, for in the rivers and basins of fresh water, crystals of ice at first appear over almost the entire surface, but in the seas which have no great depth it is generally from the bed itself that the liquid mass congeals.

In fact, salt water has not, like fresh water, its greatest density at the temperature of 39·2° F., but it becomes heavier and heavier in proportion as it freezes. The coldest strata of water, being also the heaviest, descend vertically towards the bottom of the sea, and displace the lower strata which are lighter and of a higher temperature. While the water which descends to the bottom in rivers has a normal heat of seven degrees above freezing-point, the sea-water which falls deeper may have been chilled to 32° F., or even many degrees below it. When the mass is not agitated, it remains liquid, but, on the slightest disturbance, it suddenly turns to ice. Sometimes, at the commencement of winter, the mariners and fishermen of the Baltic and western coasts of Norway find themselves suddenly surrounded by floes of ice, which rise from the bed of the sea and which still contain fragments of fucus. It appears so rapidly that the boats often run great risk of being crushed between the solid masses which are piled around them, and the crews are in imminent danger. Around the rocky coasts of Greenland, Labrador, and Spitzbergen, these ice-floes often raise huge stones which they have torn from the bed of the sea.

In the open sea ice is also formed. In winter, when the air is calm, the snow falls in large flakes on the tranquil waves, the sea is soon covered with a kind of scum, which gradually changes into a thin coating of ice. The wind may break this layer when barely formed, and the tiny scattered fragments may be surrounded with water from the melted snow, which does not mix with the salt water of the sea, and glitters feebly with iridescent hues beneath the rays of an oblique sun; but this does not last long, and the cold soon re-forms the layer of ice. Even in despite of wind and wave, innumerable needles of ice, which give to the surface of the water a pasty appearance, spread their network over the sea, and soon con-

solidate into a thick layer, which constantly increases as the cold of winter becomes more and more rigorous. By the natural chemistry of the sea, which is an immense laboratory, the mass of ice is in a great measure freed from the salt which is found in sea water; for, according to the observations of Mr. Walker, it contains hardly more than five thousandths; that is to say, about a fifth of its normal quantity. The water nearest to the new ice mixes with the expelled salt, becomes heavier, and as the freezing-point is at the same time lowered, it descends deeper in the water without becoming solid. This is the reason why in the open sea the water is rarely frozen for any considerable depth below the surface, as one might expect. According to Rae, ice of marine origin when cast ashore gradually loses its saline properties, and within two years the water flowing from it is quite fresh.

In consequence of the frequent collision of these fragments of ice tossed by the waves, they generally assume the same circular form as the flakes of ice on rivers. They are roundlets of a very inconsiderable diameter, slightly raised at the edges; the English sailors term them "ice-cakes." But the cold becoming more intense, these disks finally adhere to one another, and before long millions of them, united in vast fields, form islands which stretch to the farthest horizon. Sometimes these "ice-fields" have a superficial extent of hundreds of thousands of square miles, and even constitute, by their dimensions, real continents. Those which border upon the eastern coast of Greenland have not been melted for four centuries, and effectually prevent the approach of navigators to the land; those connected with the Siberian coasts are still more considerable, because of the long extent of shore which serves as their base. In the Polar archipelago of America, ice bars the entrances of the channels almost every year, and raises before the navigator an impassable wall. How many times have the explorers of Arctic seas tried in vain to find a passage through these barriers, and have remained imprisoned in the solid mass, after having ventured into some deceitful opening of the ice-field!

These interminable white surfaces are almost always bordered on the seaward side by blocks and disks rocking or whirling on the billows; these are the scattered islands which announce the neighbourhood of continents of ice. Those which are elevated on an average from 3 to 6 feet above the water, and the bases of which descend from 20 to 25 feet below the surface, have sometimes a tolerable uniformity of aspect, and when at times the snow covers all inequalities, the ice-field seems to be transformed into an even plain like the Russian steppes. But the ice is much more often rugged; fantastic hillocks, formed of all the wreck-fragments which the floes of ice have thrown up in dashing against each other, appear here and there several yards high. There are some which one might even confound with the enormous blocks that have fallen from the glaciers of Greenland or of Spitzbergen, and which really cannot be distinguished from them but by the slightly saline taste of the ice. These projecting masses are seen from afar above the sea, and remain erect long after the ice-field has melted. In the Siberian seas, where they give them the name of *toroses*, most of these hillocks, composed of the ice of the preceding winter, are easily melted by the first warmth of summer; but there are some which are preserved from year to year, and which remain indestructible during centuries, even under the rays of the sun. The Ostiac hunters, who frequently see these *toroses* run aground on the Siberian coast, designate them "Adam's ice," and imagining that they are contemporaneous with the origin of the world, assert that even fire itself is powerless against their crystalline masses.

In spring-time and in summer, when the great heat commences in the polar zone, the force of the currents, whose action constantly makes itself felt beneath

the ice plains, detaches from the remainder of the mass enormous fields of ice several hundred square miles in extent, and carries them far towards the open sea. The vessels of the explorers or whalers, which have been set fast in the bed of ice, are then carried out of their course with the broken field. Courageous sailors who have penetrated beyond Baffin's Bay have often thus been brought back by the current for hundreds and thousands of miles, and have only been able to regain the way they have lost at the price of most painful efforts, or have even been obliged to abandon their enterprise completely. Such was the case in the sea around Spitzbergen in 1777; ten Dutch vessels were driven with the ice more than 1500 miles towards the south-west, and shattered on the way. It was a phenomenon of the same nature which prevented Captain Parry from reaching the North Pole. He had already approached nearer to this point than all preceding navigators, and had taken a sledge to cross the ice-field; but each day, notwithstanding the great distance apparently traversed in the direction of the pole, he found himself farther than the day before from the goal towards which he marched. The reason being that the continent of ice which bore him was being itself carried rapidly towards the south. White bears are thus sometimes carried by ice-floes, and landed on the coasts of Lapland, and are frequently transported in the same way to Iceland.

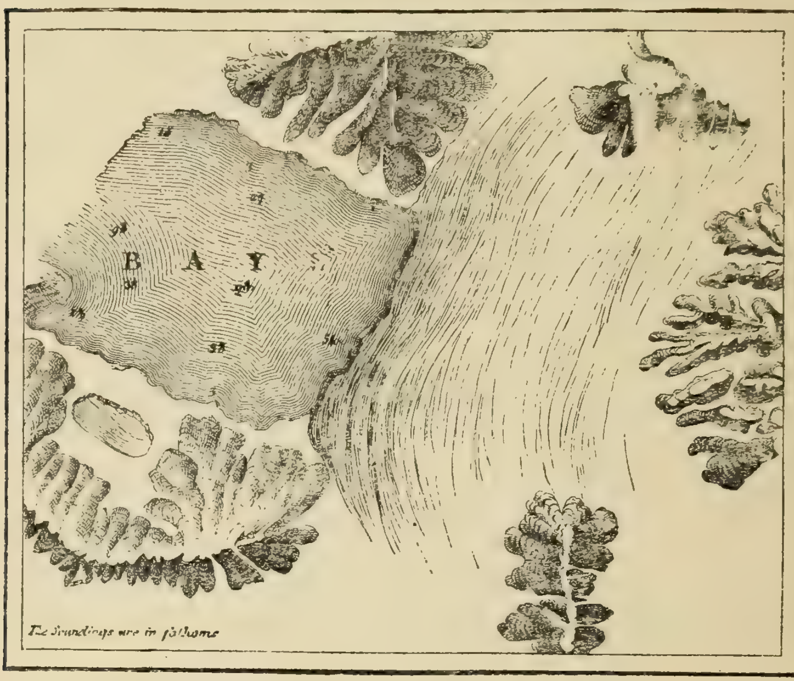
When once broken, the ice-field soon disappears; large fragments driven by the currents and the waves are dashed against each other with the enormous force which a weight of hundreds of thousands or millions of tons gives. Shattered by the terrible shock, these masses are divided into pieces of smaller dimensions; the cementing ice being destroyed by the fragments of the more anciently-formed ice-field, the turrets and pinnacles which stand here and there begin to melt and fall, and a few days after the thaw has commenced nothing remains but a few ice-floes and uneven blocks gently rocking with the waves. To account for this rapid disappearance of the ice-fields (in which the infinite tiny organisms of the sea also aid) the inhabitants of Greenland imagine that the entire mass is engulfed in the depths of the ocean. Even in the Baltic, where this phenomenon is comparatively much less remarkable, the Danish sailors, almost without exception, assert that in spring-time the ice-floes are swallowed up by the sea, although not one of them has witnessed the immersion. But what is more easily corroborated is the strange noise that always accompanies the breaking up of the ice. With the crash of the meeting ice, more deafening, more terrible than that of cannon answering to each other, with the roar of the waves, and the groaning sound from the breaking disks and the air which escapes from them, is joined a kind of crackling, similar to drops of rain falling on plates of metal. This noise, which is heard also on mountain glaciers, results, as Tyndall has shown, from the incessant breaking up of the crystals which compose the mass.

Whatever picturesque beauty there may be in the ice of marine formation constituting this field, it is far inferior to that of the masses which are detached from the glaciers of Greenland, Spitzbergen, and other countries of the North Pole. Enormous fragments may be separated from the end of the glacier in two different ways, according to the temperature of the sea into which they protrude. In Spitzbergen and on the coasts of Southern Greenland, the congealed mass, which often projects far into the sea, is gradually undermined by the comparatively warm waves which beat against it, and the remaining fragments overhanging the water are detached with a terrible noise, and plunge into the ocean. M. Martins and other members of the French expedition to Spitzbergen have observed this at the base of all the glaciers of that archipelago. But in very cold seas, like that

of Smith's Sound, the water, being of a still lower temperature, cannot melt the glacier, which continues its course into the bay, its extreme end reaching far into the depths of the ocean, like an immense plane gliding over the rocks. Though lighter than the water, the enormous frozen mass is kept below because of its cohesion to the *mer-de-glace* which drives it along. But the moment comes when that connection breaks, and obeying at last the force which its buoyancy imparts to it, it shoots to the surface, and after repeated oscillations from the change in its centre of gravity it rises in huge towers or fantastic peaks. We can imagine what a chaotic mass all these fragments, mixed with the marine ice and the remains of ice-fields, must produce in narrow bays, or in very contracted arms of the sea. It was across one of these prodigious "packs," in Smith's Sound, that the intrepid Hayes made his way with almost superhuman perseverance.

These glistening icebergs are the splendour of Arctic seas. Often of colossal

Fig. 13.—Glacier of La Madeleine, on the Coast of Spitzbergen.



dimensions, they present at times forms of almost perfect regularity, whilst at others they assume the most varied and fantastic shapes. Lofty towers, columns in pairs, with groups of sculpture, and statues, like marble divinities, rise above the sea. In comparatively warm seas like those of Spitzbergen, which are affected by the Gulf-stream, the ice is constantly worn away; and those parts of the floating masses which rise above the surface of the sea generally assume the appearance of pillars, with more or less overhanging capitals, fringed with stalactites. The summit is white and occasionally covered with snow, while the fluting of the column, where the more compact ice has been bathed by the waves, has an emerald or sapphire hue. The foundations of the columns are pierced with caves, into which the water rushes with a hollow murmur; and at times they are riddled with small holes, from which each wave springs in diverging jets. Silvery fountains burst alternately from either side of the column according to the inclination given to it

by the sea. In very cold water, like that of the Arctic Archipelago, the opposite phenomena occur. Instead of being worn away and melted by the waves, the blocks falling from the glaciers at first gradually increase in dimensions, on account of the low temperature of the water into which they are plunged, which solidifies around the foot of these enormous floating towers.

Thus might perhaps be explained the prodigious dimensions of some of the frozen masses drifting with the oceanic currents. The layers of cold water, whose temperature is several degrees below the freezing-point, remain in the liquid state so long as they continue to be at rest. But the moment their cohesion is disturbed by the sharp angular floating ice, they become transformed to frozen masses of vast extent. Then the floating ice itself, like a vessel raised on an enormous cradle, begins immediately to rise above the surface of the surrounding waters.

The larger masses detached from the glaciers are known under the name of icebergs. Dr. Wallich was able to measure some of them on the coasts of Greenland, by ascertaining the depth below water of the bank on which several of these moving bergs had been stranded; and he found that, with the regularly formed blocks, the part above the level of the sea is never more than the fourteenth or sixteenth part of that beneath the level of the water. With respect to the masses whose exposed portions terminate in a cone or a pyramid, they descend to a less depth, in proportion as they present a more considerable bulk above water. But the total height of the iceberg always exceeds by seven or eight times the visible portion.

By these proportions mariners can judge of the real size of the icy masses which they see stranded on the coasts of Newfoundland, or melting slowly as they float far out into the Atlantic. Enormous blocks have been seen from 300 to 400 feet high, so that these fragments of glaciers measured more than 3,000 feet from summit to base; that is to say, an elevation equal to the highest mountains of England or Ireland. One of these masses which was encountered by the ship *Acadia* off the bank of Newfoundland, amidst a labyrinth of other floating mountains, was about 480 feet high, surmounted by a kind of dome resembling St. Paul's Cathedral in a most singular manner. Twenty days later, when on her homeward voyage, the *Acadia* found the same iceberg 68 miles more to the south. A great number of these travelling masses have been seen, measuring several miles in length and breadth, whose bulk amounted to tens of thousands of cubic yards. As to fragments of ice-fields, some have been met with measuring not less than from 50 to 100 miles in each direction.

The slow movement of the block observed by the *Acadia,* which only advanced a little more than three miles per day, proves that icebergs offer considerable resistance to the current which carries them. The checks to which they are subject on the way, such as partial strandings, or when the surface and under currents urge them in opposite directions, retard their speed considerably, and often change them into seemingly stationary islets. Towards the end of 1855 an unexpected circumstance, still more remarkable than that of the berg seen by the *Acadia,* shows us exactly what had been the progress of an iceberg during the space of more than a year. An American whaler sailing in Davis' Strait perceived a dark mass in the middle of a group of floating peaks; this mass was the ship *Resolute,* which the British Government had sent out in search of Franklin, and which the crew, having ventured into the icepack, had abandoned to continue their way in sledges. When the vessel was found again, it had been already detained in its floating prison for sixteen months, and during that space of time

had only been carried about 870 miles, counting the necessary turnings through Barrow's Strait and Lancaster Sound. Thus the ship, abandoned in the Polar sea, had not exceeded the speed of 130 yards per hour in its progress towards the Atlantic, which is a hardly perceptible advance. In the history of the great Arctic expeditions three other vessels are mentioned, which were carried in the same manner towards the ocean, but without having been abandoned by their crews; these were the ships of Sir John Ross, of Lieutenant de Haven, and of McClintock. The last-named navigator was a prisoner for 242 days, and advanced about 1120 miles towards the south, that is to say, about 346 yards per hour.

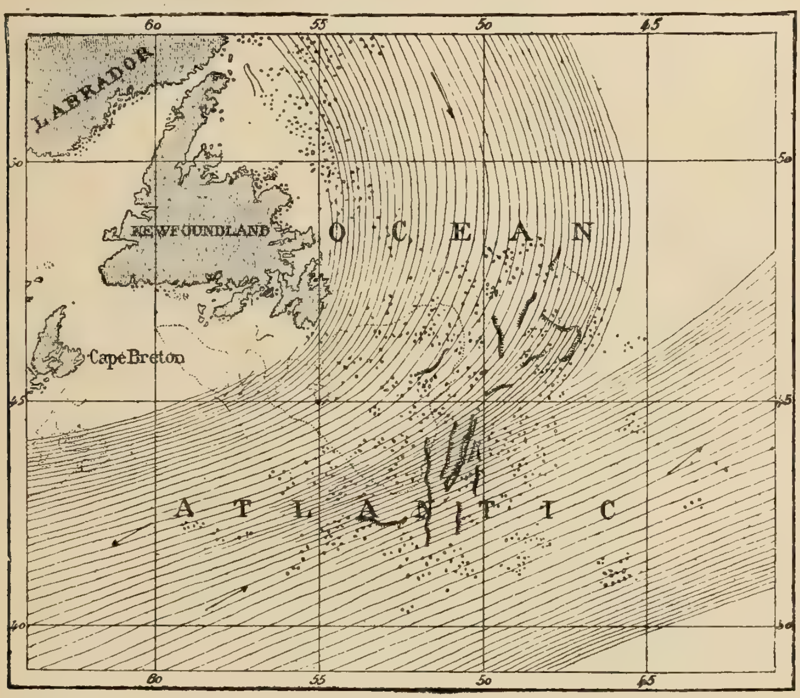
The enormous masses of icebergs like gigantic ships are often stranded on shoals, even where the depth of the sea exceeds a hundred fathoms. Arrested in its southward drifting, the immense block gradually dissolves or divides into fragments, which in their turn are stranded on some other bank, at a less depth. Day by day the waves melt and destroy a great quantity of ice, which then lets fall the gravel and stones with which it was charged, and in this manner continually raises the sea-bottom. Every year new beds of rock, pebbles, and earth from the mountains of Greenland and the archipelago of North America are thus deposited on the Bank of Newfoundland, and in the neighbouring seas, laying the foundations of a new continent. Doubtless the Great Bank, which extends over a tract of above 55,000 square miles, and which has its foundation in a sea of about four to six miles deep, is composed entirely of this moraine-matter of glacial origin. Thus during a long series of ages the ice-floes have been labouring without relaxation to demolish the Arctic lands, and to construct new continents in the seas of the temperate zone.

From the time of the breaking up of the northern ice, that is to say, from the beginning of March to the month of July and even to the month of August, that part of the Atlantic to the east of the bank of Newfoundland assumes the appearance of the Arctic sea. The Polar current, descending from Baffin's Bay parallel to the coasts of Labrador, brings with it in long procession the fragments of the ice-fields and glaciers of Greenland. After having rounded the bank of Newfoundland, the current bends towards the south-west with its burden of ice, in consequence of the movement which carries the earth in an easterly direction and causes a deviation from its course in everything coming from the north. Carried by this current, which drives them in the opposite direction to the Gulf-stream, continuing its course towards the south-west below the surface current of the latter, the icebergs, like ships cutting the waves with their prows, pass majestically through the water which dashes against them. Some fragments of mighty ice-fields, brought from Greenland by Polar currents and then drifted northward by the Gulf-stream, are seen here and there proceeding in an opposite direction from the rest. The accompanying map, borrowed from Redfield, indicates the position of all the icebergs and ice-fields recently observed in the western part of the North Atlantic Ocean.

It is principally in this region of the ocean that flotillas of ice are to be dreaded by navigators. The sailors of Newfoundland hardly ever approach one nearer than about a mile, and then always keeping to windward of them, for otherwise they would be in danger of drifting upon the terrible mass, towards which in addition a somewhat strong current is always flowing to replace the upper stratum of water rendered colder by contact with the floating mountain. Enveloped in fog in consequence of the lowness of their temperature compared with that of the warm humid air from the south, the gigantic hull of the glacier discovers itself to

seamen by strange whitish reflections and also by the intense cold of the surrounding atmosphere. But sometimes when this indication of peril has just been recognized it is too late to avoid the shock. Hundreds of ships overtaken by the ice have thus disappeared with their crews in the cold waters of the ocean. At other times, even in clear weather, one meets with a whole archipelago of ice-floes; and in order to avoid them it is necessary to steer with the greatest precaution for days together. It was thus that in 1821 the English brig *Anne*, surprised by the ice off Cape Race, not being able to enter a free sea, was obliged to remain 29 days surrounded by towers and threatening peaks. Happily these fragments of glaciers diminish very quickly in number and height as soon as they enter the zone of the Gulf-stream. Worn away at their base by the tepid waters of that current they capsize, break, and dissolve so completely, that towards the 40th

Fig. 14.—Course of the Icebergs between Europe and America.

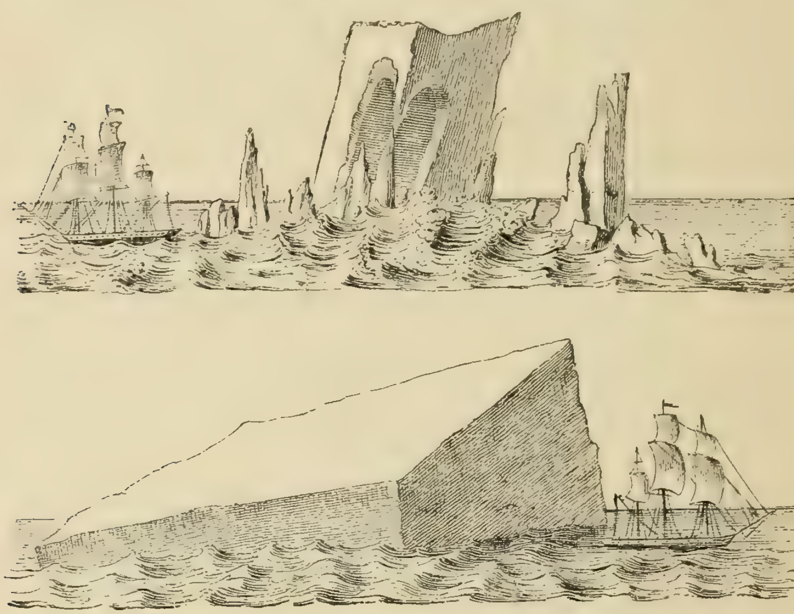


degree of latitude it is rarely that any fragments even remain. However in June, 1842, the ship *Formosa* encountered in 37° 30′ of north latitude a floating iceberg 30 yards high and 50 yards long moving towards the south. Masses of ice bearing the remains of a Norwegian vessel were seen by Couthony under the 36th degree north latitude between Gibraltar and the Azores; and mariners even speak of icebergs reported to have been met near Cuba, in the 22nd degree north latitude.

In the Antarctic hemisphere, exactly similar phenomena occur. Thus, as is proved by numerous observations, more than 860 of which have been regularly catalogued by Fitzroy and other geographers, the ice-fields and fragments of glaciers of the southern continent float likewise in the direction of the equator. But it seems that the icebergs of the southern hemisphere generally present less variety of form than those of the opposite zone. They are not peaks and domes with fantastic outlines, but rather resemble walls rising like rocky precipices to an

elevation of about 160 to 200 feet; these floating masses are probably, however, on an average of still more considerable dimensions than the masses which fall from Arctic glaciers. The massive form of these floating mountains of the southern seas must doubtless be attributed to the severe cold which prevails in the south polar zone, which drives the snow and glaciers of the Antarctic lands farther into the open sea. Even at the 50th degree of south latitude, ships meet with ice-fields of a size equal to those which on the other side of the earth are only found within the polar circle. In the northern hemisphere the ice-rivers of Greenland and Spitzbergen are not fed by a sufficient quantity of snow to carry them completely out of the bays into which they flow, and into the open sea. Retained in their course by steep lateral cliffs, promontories, and rocky islets, they assume in consequence of all these obstacles a much more irregular form than they would have if they penetrated into the free ocean, like the glaciers of the South Pole. The latter are drifted far out of the gulfs, beyond the capes even, and they are

Figs. 15 and 16.—Icebergs of the Antarctic Ocean; after Wilkes.



only occasionally attached to the submarine base of the continent. In front of this ice-sheet float innumerable islands, through which ships can with difficulty find their way. Thus during the exploring voyage of Wilkes, the *Peacock* had to steer for a long time in a labyrinth of blocks which threatened to crush her.

The breaking up of the Antarctic ice occurs in spring and summer, like that of the North Pole, but six months later, in consequence of the opposition of seasons in the two hemispheres, caused by the obliquity of the earth's axis. The scattered pieces of ice met with during winter are only fragments detached from the ice-fields. Vessels traversing the Antarctic Ocean meet with thirty or forty times more ice in December, the height of summer, than in July, which is the coldest time. The multitude of floating masses varies much in these seas. To the south of Australia and New Zealand icebergs and ice-fields are comparatively rare. To the south of Cape Horn they are met with more frequently, but are never seen between this southernmost point of America and the Falkland Islands; for owing

to the great polar current they all drift towards the north-east. It is to the south of the African continent that the ice is carried in the greatest quantity, and approaches most nearly to the equator. Some has even been perceived from Cape Town in 34 degrees of south latitude. Thus the Antarctic icebergs are carried about 250 miles nearer the torrid zone than are the Arctic masses.

In the inland seas exposed to severe cold, the congelation of the water is produced in the same way as in the ocean; the phenomena only differ in proportion. Thus the ice of the Baltic is far from presenting such a grand spectacle as the icefields of the Polar seas, but its mode of formation is known in a much more complete manner; for during a long series of years, conscientious observers have studied its various changes, from the formation of the first ice to the general

Fig. 17.—Route of the "Peacock," Commander Wilkes, U.S. Navy, in the Antarctic Ice-pack.

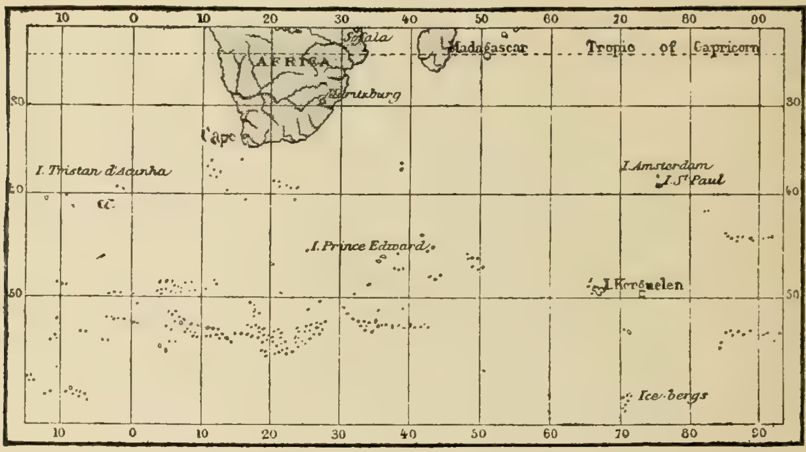
breaking up. These researches have proved that after having been formed, the icy bed of the Baltic is subject to the same phenomena as that of lakes, not only in the northern parts of the sea where the water is almost fresh, but near the entrance also where the mass of fluid is still strongly saline. The crevasses in the ice do not differ essentially in their formation from those of Lake Baikal or the Lake of Constance. They also open with a thundering noise, letting a great quantity of water escape, which freezes in its turn and thus increases the thickness of the solid bed. Around the island of Oesel the fissures vary from six inches to more than six feet, and are continued for a distance of several miles. But the surf produced by the currents and the dashing of the waves, where the sea is not frozen, gives the most varied directions to the crevasses; in some places they are

parallel, while in others they intersect one another irregularly or radiate towards all points of the horizon.

Ice very rarely covers the surface of the sea while the water is much agitated. Tempests or rapid currents retard, or even completely prevent, the formation of the ice-sheet. Thus, while on the east, where the sea is calm, the island of Oesel is, on an average, united to the mainland during 130 days of the year by a layer of ice sometimes attaining a thickness of more than three feet, and serving as a high road for sledges, the western cliffs, against which the surges strike, are, on the contrary, only bordered by a narrow fringe of ice. On the promontory of Muhha Ninna the waves always break with fury, and this extreme agitation of the water lasts during the whole winter, preventing the appearance of the least particle of ice; indeed the peasants of the island say that they have never seen any near this point.

Every year, a considerable part of the Baltic is covered with ice. Almost all the Gulf of Bothnia and the entire coast-line of the Gulf of Finland is changed into a white and immovable surface, the islands and islets are encircled by a zone of ice-floes, more or less wide, whilst the straits of a slight depth are similarly

Fig. 18.—Course of Icebergs in the Southern Hemisphere.



obstructed. Every winter Finland is reunited to Sweden by a bridge of ice, pierced here and there by the innumerable rocks of the Oeland archipelago. This solid crust then becomes for many months the highway between Sweden and Russia. The Baltic, like the Polar ice-fields, has its piled-up masses of ice resembling turrets, pyramids, and obelisks built upon the sea; from these fields, also, broad masses are detached from their edges to float towards the south with the current, then breaking with a loud crash, are similarly reduced into scattered pieces; and in a few days after the commencement of the thaw only thin fragments remain, tossed here and there by the waves.

During the last few centuries the Baltic Sea has never been entirely covered with a field of ice. But the chronicles inform us that in 1323 the southern part of the basin was completely frozen over, and during six weeks travellers from Copenhagen repaired on horseback to Lubeck and Dantzic; and temporary hamlets were even erected on the ice at the intersection of the roads. During the winters of 1333, of 1349, 1399, and 1402, the same phenomena of general congelation occurred in the southern Baltic, and the icy bed served as a road for commerce between Pomerania, Mecklenburg, Denmark, and the islands. In 1408 the ice-

field completely closed the entrance of the Baltic between Norway and Jutland, and extended through the Cattegat, the straits of the sea of Scania, into the Baltic, as far as the large island of Gothland. It is said even that the wolves of Norway, driven from their native forests by hunger, crossed the Skagerrack to invade the villages of Jutland. Since this epoch, several parts of the southern Baltic have been frozen over again ; but the solid surface has never presented the same extent, nor the same consistency. This fact would seem to prove that the mean temperature has become milder in Northern Europe since the fourteenth century, while according to Adhémar's hypothesis exactly the contrary is the case.

It is a remarkable fact, that save in a few exceptional years the Black Sea, which is exposed to all the piercing winds which descend from the Polar regions, has never been invaded by ice like the Baltic. During the earlier historic ages the Sea of Marmora and the surface of the Euxine have been frequently covered with ice ; which proves that, at least during this period of frost, the temperature of Constantinople was no higher than that of Copenhagen. In the year 401 of the present era the Black Sea was almost entirely frozen over, and when the ice broke up, enormous icebergs were seen floating in the Sea of Marmora for thirty days. In 762 the solid layer which covered the Euxine extended from one bank to the other, from the terminal cliffs of the Caucasus to the mouths of the Dniester, Dnieper, and the Danube. Moreover, contemporary writers assert that the quantity of snow which fell on the ice rose to the height of twenty cubits (from 30 to 40 feet?), and completely hid the contour of the shores, so that one knew not where the land began or the sea ended. In the month of February, the broken masses of the ice, carried by the current to the entrance of the Ægean Sea, reunited in one immense sheet between Sestos and Abydos across the Hellespont.

Subjoined is an account, contributed by Mr. Alexander Graham Bell to *Science*, of a practical method proposed by Mr. Frank Della Torre for preventing collision with icebergs in a fog.

Mr. Della Torre's experiments indicate the possibility of obtaining an echo from an iceberg when in dangerous proximity to a ship. He believes that even an object offering so small a surface as a floating wreck may in this way be detected during a fog in time to prevent collision. However this may be, it is certain that his method is worthy of a careful trial at sea, and that preliminary experiments, recently made in the presence of Prof. Rowland, of Johns Hopkins University, and the present writer, have demonstrated the feasibility of producing well-marked echoes from sailing-vessels and steamboats at considerable distances away.

These experiments were made on the River Patapsco, near the head of Chesapeake Bay, at a point about seven miles from the City of Baltimore. The party proceeded down the river in a steam-launch to the selected place, where the distance from shore to shore appeared to be about three miles.

The launch was kept so far from land as to prevent the possibility of mistaking an echo from the shore for one produced by a passing vessel.

The apparatus employed consisted of a musket, to the muzzle of which a speaking-trumpet had been attached. This gun was aimed at passing vessels, while blank cartridges were fired. After a shorter or longer time, according to the distance of the vessel, an echo was returned.

The ordinary river-steamboats, and schooners with large sails, returned perfectly distinct echoes, even when apparently about a mile distant. At shorter distances the effects were, of course, still more striking.

In order to test the effects under the most disadvantageous circumstances,

blank cartridges were fired in the direction of an approaching tug-boat. The surface presented was, of course, much smaller than if the boat had presented its broadside to the launch. As the boat approached bow on it corresponded to a target somewhere about six feet square, presenting a convex surface to the impinging sound-wave. Even in this case a feeble echo was perceived when the boat was at a considerable distance (estimated to be nearly one-quarter of a mile). That any echo should have been perceived at all under such circumstances was a surprise. The sound was heard only by the closest attention, but in the case of larger vessels the effects were very distinct and striking.

Experiments were made which demonstrated the fact that the speaking-trumpet attached to the gun was of material assistance in giving direction to the sound-impulse, and in intensifying the audible effect.

Mr. Della Torre claims that a steam-whistle or siren, combined with a projecting apparatus like a speaking-trumpet, will prove as efficient as the gun.

During the experiments on the Patapsco River a curious rumbling effect like the rolling of thunder was often observed, which continued for some seconds. A similar sound was noticed, as an echo from a well-wooded shore ; but the effect alluded to above could not have been due in any way to the land, as the sound commenced immediately upon the firing of the gun, whereas the shore was distant at least a mile or a mile and a half.

The sound was probably due to the presence of ripples on the surface of the water, as the effect was much less marked when the surface was smooth. Such a sound might prove a disturbing element of importance in a rough sea, but would hardly be sufficient to prevent detection of an echo from a large iceberg. Had shots been fired periodically from the bow of the *City of Berlin* it can hardly be doubted that the presence of an obstacle ahead would have been discovered in time to prevent the collision that actually occurred.

CHAPTER VI.

WAVES OF THE SEA.—REGULAR AND IRREGULAR UNDULATIONS.—HEIGHT OF THE WAVES.—THEIR SIZE AND SPEED.—GROUND-SWELL.—COAST-WAVES.

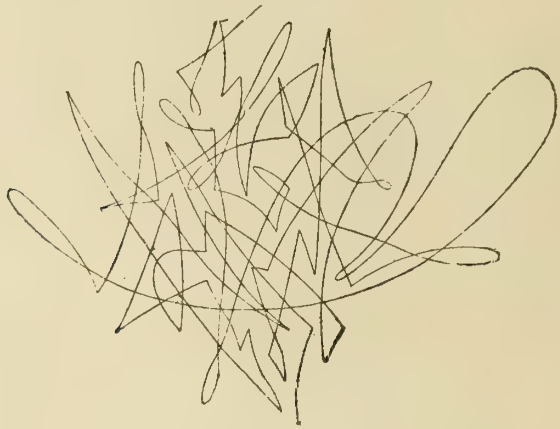
THE sea rarely presents a glassy surface. When the atmosphere is calm, which however is commonly the case before a tempest, the water is sometimes so very smooth that every object is reflected by it with a perfectly sharp outline; the only changes which seem to affect the vast motionless sheet of water are those produced by the mirage, which makes the distant horizon glitter like a long band of silver or steel; the fishermen then say that "the sea is reflecting itself." But this tranquillity of the water is a very uncommon phenomenon, except in the Mediterranean and other seas where there is only a slight tide. Usually the wind, either in breezes or tempests, now aiding and now retarding the ebb and flow, raises the sea into waves, more or less high, which sometimes roll onward regularly, or are dashed against and across one another. Even during calms, the waves, still obeying the impulse of recent winds, continue to roll across the ocean in long undulations. One of the grandest spectacles at sea is offered by these regular movements of the waves in perfectly calm weather, when not a breath stirs the sails; high, blue, and foamless, the liquid masses succeed one another at intervals of 200 to 300 yards, pass under the ship in silence, and pursued by other waves are lost in the far distance. One contemplates with a feeling of admiration, not unmixed with terror, the calm and majestic wave advancing like a moving rampart, as if about to swallow up all before it, and yet hardly leaving a sign to mark its passage. These waves appear with surprising regularity, during the autumnal calms, under the tropic of Cancer, and almost at every season in the narrower part of the Caribbean Sea towards the Gulf of Darien; there the waves are seen silently to advance, and slightly raise the ship, passing onward with scarcely a murmur, as regularly as the furrows of a field, and stretching as far as the eye can see.

Such perfectly regular waves as these can only be formed in seas exposed to the influence of equable winds, such as the trade winds. Wherever the winds are uncertain and shifty, blowing in gusts, it is evident that the waves driven by them cannot assume a regular form or follow in a uniform direction. For aërial currents constantly vary in their speed, being composed of strata of unequal force, which moving at a rate different from that of the surface of the sea, alternately increase and diminish in force. Under the influence of these variable atmospheric impulses, the waves must necessarily vary in height and speed, and their crests cannot be developed in a uniform line. The wind also frequently changes its direction; as if urged by some new impulse, it commences blowing from another point of the

compass, and drives the waves in a different direction from that which it had itself given them. Nevertheless the first movement is continued by the succeeding waves even while the second is still making itself felt, and from this double impulse an intersection of waves, differing from one another in direction, height, and speed, results. Let the wind shift to another point of the compass, and a third undulation crosses the preceding two. Finally, should the aërial current make the complete circuit of the compass, the ripples of the water pursue one another in all directions urged from all points of the immense circle. Not a breath is lost on the sensitive surface of the sea, and the variety of its undulations testifies to the diversity of the aërial movements which cause them.

From a lofty headland or from the mast of a ship, whence a vast expanse of water can be viewed, the beautiful sight may be often enjoyed of two or three systems of waves intersecting each other at various angles. Now they double the natural height of the undulations, by piling one wave upon another, and then again they equalize the surface of the water by throwing billows into the furrows. Sometimes the sea is so agitated that it is impossible to discern the direction of all

Fig. 19.—Rolling of a Ship upon the Waves.



the waves which have aided in producing the violent commotion. As to the voyagers, whom the wave-tossed ship incessantly shakes by its rolling and pitching, it is still more difficult for them to recognise in the intersection of the waves the impulses communicated to the sea by the atmosphere. The accompanying figure is reproduced from that of an English traveller, of the curves drawn during a single minute by a pencil suspended vertically in the cabin of a ship. At the time when the pencil traced these lines, the wind was low and the motion of the water very moderate.

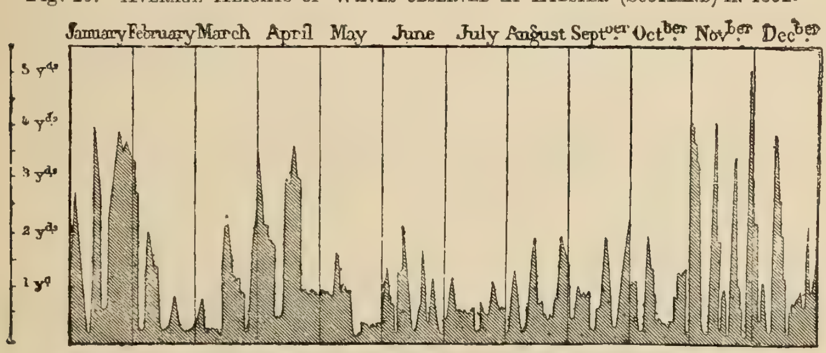
The height of the waves is not the same in all seas; it is greater when the basin is deeper in proportion to the exposure of its surface to the wind, and also in proportion as the water, being less salt and so lighter, yields more readily to the atmospheric currents. Thus assuming equality of surface, the water of Lake Superior would be raised in higher waves than that of a gulf of the sea barred on the open side by islands and sandbanks. When of equal saltness, the narrowest basins ought to present the shortest and least elevated waves. The waves of the Caspian Sea are not to be compared with those of the Mediterranean, which again

are greatly exceeded in height by those of the North Atlantic ; and these latter in their turn are surpassed by those of the Antarctic Sea, which spreads over an entire hemisphere.

According to Admiral Smyth, who was well acquainted with the Mediterranean, the tempest waves rise from 13 to 18 feet in vertical height above the trough of the sea. He has even seen quite exceptional waves rise to the height of above 30 feet, but the average waves raised by high winds were only from about 10 to 13 feet. In one passage from Liverpool to Boston, which the celebrated navigator Scoresby made in 1847, he measured waves from 26 to 29½ feet, and the average of all his observations gave a height of about 19 feet for the largest waves. On his return in 1848, he found the average to be 30 feet, and some among the waves he measured rose to about 43 feet above the trough of the sea. Other navigators have given similar estimates for the highest crests of waves in the North Atlantic; but the mean elevation is much less. One can form a good notion by the following diagram, drawn by the engineer Middlemiss to represent the annual variations of the waves at Lybster, on the coast of Scotland.

In the South Atlantic the height of the waves is certainly greater than in the northern section. Many seamen have seen the water rise between 50 and 60 feet off

Fig. 20.—Average Heights of Waves observed at Lybster (Scotland) in 1852.



the Cape of Good Hope, where the basins of the Atlantic and Indian Oceans meet. Dumont d'Urville even asserts that he has seen waves above 108 feet high, to the depths of which the ship descended as into a valley, and M. Fleuriot de Langle attests the truth of this assertion. These are indeed the mountains of which poets speak, and which, in fact, seem such to those who find themselves at their mercy. It is probable, too, that the highest waves of the sea have not yet been measured. One remarkable fact is, that it is not usually during the most violent tempest that the hugest waves are formed. On the contrary, the force of the atmosphere which then precipitates itself obliquely on the waves, so to speak, depresses and crushes them.

The waves are developed in all their majesty when the wind is at the same time very high and very regular, and blows for a long time from the same point of the compass.

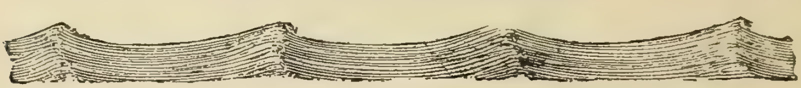
As to the width of the waves, that is to say, their total breadth from base to base, observers have not obtained the same results; but there are few among them who have found the vertical height of the crest of the wave to be less than a twentieth or more than a tenth of the width. On an average the height of an undulation of the water is only equal to the fifteenth part of its base ; thus a wave

of 4 feet in height measures 40 feet from valley to valley, and a wave 33 feet high is 495 feet in width. This is a much smaller size than would be imagined by the sailor lost in the midst of the billows, which he sees rising around him in every direction. Moreover, the inclination of the waves varies with the force of the wind and the movements of the secondary undulations which intersect the principal ones. The passage from trough to trough varies from four to nine seconds in the English Channel, the Mediterranean, and the Bay of Biscay.

The speed of the waves is only an apparent speed, like that of the folds of a cloth, raised by a current of air. Thus although the water pressed by the wind rises and sinks by turns, it nevertheless hardly changes its place, and objects floating on its surface move but slowly and in an undulatory manner. The real movement of the sea is that of a drifting current which gradually forms under the prolonged action of the wind; but this general movement of the liquid mass is after all inconsiderable. The only part which advances with the storm is the foaming crest which, curling over the summit of the waves, dashes down the slope in front. By their incessant movements, the surface of the waves gradually increases in temperature, as has been observed after a succession of violent storms.

The apparent displacement of the billows (which is rather difficult to measure with exactitude in the open sea) varies in a regular manner, according to the magnitude of its waves and the depth of its waters. Thus according to the calculations of the astronomer Airey, every wave of 100 feet in width, traversing a

Fig. 21.—Average Amplitude of Waves.



sea of 164 fathoms mean depth, has a velocity of nearly 21 feet per second, or over 14 miles per hour; a wave of 674 feet, moving over the surface of a sea 1640 fathoms deep, travels more than 69 feet per second, or about 47 miles per hour; this last figure may be considered as an average speed for storm-waves in great seas. Since, therefore, we can by calculation infer the velocity of waves from their width and the known depth of the ocean-bed, it is easy to determine by an inverse operation what is the depth of the ocean itself, provided that we know the rate of motion of the waves. It is by this method that the means of the South Atlantic and of the Pacific Ocean between Japan and California have been calculated.

Natural philosophers have frequently discussed the question of the movement of the waves in a vertical direction. To what depth in the abysses of the sea does the action of the superficial wave penetrate, and at how many fathoms can it disturb the sand and debris at the bottom? It was formerly admitted, as a well-ascertained fact, but without proof, that the agitation of the sea ceases to be felt at 4 to 6 fathoms below the surface. Direct observations made by seamen in many latitudes have shown that this opinion is erroneous. Sailors have frequently seen the waves break at 10, 16, and even 27 fathoms of depth over hidden rocks, which proves that the rocks were obstacles which abruptly barred the advance of the lowest part of the wave. Still more frequently, during violent tempests, the water has been seen charged with clay and mud, which had been raised from the bottom at 50, 80, and even 100 fathoms below the surface. The direct experiments of Weber on the movements of waves have likewise proved that each wave extends its influence in a vertical direction

to 350 times its height. Thus every wave of about a foot in height makes itself felt on the bed of the North Sea at a depth of 50 fathoms; whilst every oceanic billow of 33 feet is felt at about $1\frac{3}{4}$ miles. It is true that at these enormous depths the action of the wave is, so to speak, imaginary, for below the surface it decreases in geometrical proportion; but at about 25 to 50 fathoms only, the submarine waves have still great force, and we can easily understand that when thousands of them are abruptly arrested by submarine rocks, and on the rapid slopes of sandbanks, violent eddies must be produced, which afterwards returning to the surface of the water cause "heavy swells." From these causes arise those turbulent seas which ships encounter at times in calm weather, especially in the neighbourhood of submarine banks; also those "ground swells" which suddenly raise the surface of the sea and endanger boats; and those formidable tide-races which, springing from the depths of the ocean, advance abruptly upon its sloping beaches, destroying all they encounter on their way.

It is along the shores of continents and around rocky islands that ordinary waves and heavy surf appear in all their grandeur and assume dimensions truly formidable. In accordance with the more or less gradual inclination of the bottom to the shore, a wave coming from the open sea rolls over a bed more and more shallow, and must perforce slacken its speed; but at the same time it increases by its own depth the stratum of water which it overflows, and consequently the wave which follows it is subjected to less retardation of the impulsive force. The second wave constantly gains on the first, and finally reaches it, swelling its crest, and slackening its own speed in its turn, gives a third wave time to distance it also. Finally near the strand the liquid mass, swelled by the pursuing waves, and unable to spread out further at its base along the shore, which is too near, gains in height what it wants in breadth, and rising like a wall, it bends over with a wide curve in front, and breaks with a thundering sound, throwing water mixed with sand and foam far along the shore. This surge, which is dreadful indeed during tempests, rises much higher than the waves; to the ancients the whitening billows of the open sea, whose crests were seen to shine like the fleeces of sheep, were the flocks of Proteus; while the waves of the shore, still called in our days *cavalli* and *cavalloni* by the people of the south of Europe, were the foaming horses of Neptune.

The height to which the crests of some of these waves attain when the configuration of the coast favours the movement, seems sometimes to partake of the marvellous. The mass of water which rises vertically can then only be compared to an ascending cataract. Spallanzoni relates that sometimes, in violent tempests, the waves reach half-way up or even to the top, of Stromboluzzo, a peak of lava which rises near Stromboli 318 feet above the mean level of the sea. The Bell Rock lighthouse, which rises boldly to 112 feet in height on a rock off the Scottish coast, is often enveloped in waves and foam even long after the tempest has ceased to disturb the sea. Smeaton also saw waves covering the Eddystone lighthouse, and leaping in a spout of water 82 feet above the lantern; the mass which is thus raised around the edifice cannot be less than from 2616 to 3924 cubic yards, and would weigh as much as a large three-decker. After these great storms, salt pools are scattered here and there on the tops of the cliffs.

The pressure exerted by these masses of water, hurled with such impetus, is no less surprising. Thomas Stephenson ascertained that the force of the sea dashed against the Bell Rock lighthouse amounted to about 17 tons for every square yard. In the island of Skerryvore the heaviest calculated pressure is about $3\frac{1}{2}$ tons for every yard, that is to say, more than $6\frac{1}{2}$ lbs. avoirdupois for every 0·16 of a

square inch. With such a force the displacement of blocks which seem enormous to us, is only child's play to the tempest waves. Before all sea-ports and road-steads where great works such as sea-walls and breakwaters have been constructed, seamen have been able to observe the prodigious power of the angry water. On all the exposed works at Holyhead, Kingston, Portland, Cherbourg, Port Vendres, Leghorn, the waves have been seen to seize blocks weighing several tons, and hurl them like playthings over the dikes. At Cherbourg the heaviest cannon on the rampart have been displaced; at Barra Head, in the Hebrides, Thomas Stephenson

Fig. 22.—Bay of Saint Jean de Luz.

states that a block of stone of 43 tons was driven more than $1\frac{3}{4}$ yards by the breakers. At Plymouth, a vessel weighing 200 tons was thrown without being broken to the very top of the dike, where it remained erect as on a shelf beyond the fury of the waves. At Dunkirk, M. Villarceau has ascertained, by the most delicate measurements, that during a heavy sea the ground trembles at nearly one mile from the shore.

In the Bay of Biscay, so frequently visited by tempests, the waves, coming from the west and north-west, are drawn into a sort of funnel, and hurl themselves against the shores with a force at least equal to that of the waves in the Channel

and the English seas. The works constructed by engineers to protect the roads and ports against this terrible pressure have been frequently swept away, or much damaged by the waves. Man must incessantly continue the strife he is engaged in with the sea, under pain of seeing the work of a century destroyed in a day. During the winter of 1867 and 1868, M. Palaà says that blocks of masonry, 36 tons in weight, placed at the extremity of the dike at Biarritz, were thrown horizontally from 11 to 13 yards; one block was even raised nearly 7 feet, carried over the breakwater, then thrown down, and rolled to a great distance during the storm. At St. Jean de Luz the surge is perhaps still more terrible, and some of the masses of stone employed in constructing the breakwater of Socoa, at the entrance to the roadstead, are not less than from 80 to 90 cubic yards. And yet even this strong wall would not be strong enough, if it was not additionally defended by stones scattered loosely here and there, forming a range of protecting rocks in front of the dike upon which the sea expends its fury.

The only places where the waves display a still greater power than in the Bay of Biscay, are those that are sometimes ravaged by the tornados. In the Isle of Réunion there is to be found in the middle of a savannah, a massive block of madreporic stone, which is no less than 510 cubic yards in size. It is a piece that the waves have detached from a reef and driven before them across the land. How can we wonder that waves strong enough to hurl such projectiles can alter the shores in such varied ways, demolishing the cliffs here, and forming islands there, or constructing sandbanks at the entrances to gulfs.

CHAPTER VII.

GREAT MOVEMENTS OF THE SEA.—GENERAL CAUSES OF CURRENTS.—THE FIVE OCEANIC STREAMS.

CURRENTS, that is to say, the real movements of the sea, much less visible to the eye than the apparent displacements which constitute the waves, are, notwithstanding, of much greater importance in the economy of our planet. By their action enormous volumes of water, thousands of miles wide and hundreds of fathoms deep, move across the oceanic basins; the water of the polar seas is carried to equatorial regions, while these on their side send their waves in the direction of the poles. The liquid mass circulates incessantly, as if in a vast whirlpool, in every ocean of the globe, and we can follow in thought its gigantic circuit from the fields of ice to the warm atmosphere of the tropics. Currents are indeed only the ocean itself in motion, and by their action the waters of the sea are successively distributed over all parts of the globe They are the windings of the great " salt river " of Homer, which rolls around the earth in one immense circuit. Every drop that has not already been raised in vapour to commence its long journey through clouds, mists, glaciers, and rivers, continually changes its place in the abysses of the sea ; it descends to the bottom, or mounts to the surface; it moves from the equator to the pole, or from the pole to the equator, and thus traverses all parts of the ocean. It is to this continual displacement of its innumerable particles that the sea owes its uniformity in such a surprising manner, under all latitudes, as regards the appearance, composition, and saltness of its waters.

Every difference of level which is produced on the liquid surface in consequence of prolonged winds, heavy rains, or very active evaporation, causes, as a necessary result, the formation of a current; for water, whether salt or fresh, ever seeks its level and incessantly flows from the more elevated places towards the depressions. Every atmospheric variation has, for result, a displacement in one direction or another of the superficial water. But the great currents which flow with a regular movement around the basins of the ocean, between the polar and the equatorial zones, are determined by general causes acting at the same time on the entire planet. These causes are the sun's heat, the trade winds, and the rotation of the earth on its axis.

The equatorial basin, incessantly heated by the solar rays, loses a great quantity of water, which is transformed into vapour, and rises into the higher strata of the atmosphere to be condensed into clouds. Admitting that the annual evaporation is about 14 feet, which is probably below the reality, the quantity of fluid raised from

the Atlantic in the tropical zone would be nearly 120 trillions of cubic yards, and would consequently represent the same value as a cubic mass of water nearly 30 miles in extent. It is true that a considerable part of this vapour, the half perhaps, falls as rain into the sea from which it was taken, yet a great proportion of the clouds are carried by the trade winds and other aërial currents, into seas situated beyond the tropics, and over the neighbouring continents. Near the equator, therefore, much more water is drawn from the ocean by evaporation than is returned to it by the clouds, and in consequence an immense void is formed which can only be filled by the waters from the polar basins, where the contributions of snow, rain, and ice exceed the loss in vapour. This superabundant mass of fluid continually flows towards the basin of the torrid zone, and forms the two great currents which meet one another from the opposite poles in the Atlantic and the Pacific, incessantly describing a regular orbit like the celestial bodies. But the excess of evaporation which occurs in tropical waters is not the only reason of this great movement of the polar seas towards the torrid zone. The trade winds, attracted by the force of equatorial heat, blow incessantly in the same direction, and always driving the waves before them, thus accelerate the march of the oceanic current.

In fact the theory advanced by Croll, Zöppritz and other recent meteorologists, that the trade winds setting constantly in a given direction, are the main cause of the great marine currents, seems to be now generally adopted by naturalists. "The winds," remarks A. Blytt (*Nature*, July 15th, 1886), "set the surface of the sea in motion, and by frictional resistance the movement is conveyed to lower depths. It depends on the force and the duration of the wind how deep the action will have effect. The main current runs in the direction of the prevailing wind, and its speed is dependent on the average speed of the surface. Winds of short duration are only capable of changing the direction of the current on the surface; but *through the predominance of such winds for thousands of years, great currents are created.* Their strength may vary, but their direction is independent of temporary changes of the wind. For the upper system of currents, which alone affects the climate, and which reaches to a depth of a couple of hundred fathoms, according to Mohn, the average direction and force of the wind during the last great geological epoch are determining causes."

If the mass of water which continually flows from the poles to the equator were exactly equal in quantity to that which is evaporated by the sun's heat, the arctic currents would be arrested under the tropics, and no return movement would be produced towards the polar oceans. But the waters which flow from the north and south are always in excess, in consequence of the continual impulse of the trade wind; and when they arrive in tropical latitudes they are influenced by a new current, the true cause of which is the rotation of the earth on its axis. In fact, owing to the incoherence of its particles, the ocean does not obey in an absolute manner the rotatory motion of the earth, which carries it from west to east. In descending from the poles to the equator, and thus crossing latitudes whose speed of rotation is greater than their own, they are constantly drawn obliquely towards the west, and this continual retardation of their motion behind that of the rotation of the globe becomes, in relation to the surface of the sea, an apparent motion from east to west. Upon their meeting in the tropics, the polar currents, being both affected by a side movement, strike each other obliquely, then re-unite in the same oceanic river, and flow directly towards the west in the opposite direction to that of the solid earth. It is thus that the equatorial current is produced which, with the two polar currents determines all the movements of the waters in each

oceanic basin. The other rivers of the sea are simply branches from them, caused by the form of the continents.

The equatorial current, which is a continuation of the polar currents, and forms with them a vast semicircle, cannot be freely developed around the circumference of the globe. Arrested in the Atlantic by the American continent, in the Pacific by Asia and the archipelago which unites that continent with New Holland, it breaks against the shores and divides into two streams which flow back in the direction of the poles, the one descending towards the south, the other ascending to the north. The immense river thus returns to its source, but at the same time the motion of terrestrial rotation, which at its outset caused it incessantly to deviate towards the west, now urges it obliquely in the opposite direction. Under the equator, the angular speed of the terrestrial surface around the axis of the planet being much more considerable than under any other latitude, the waters coming from the tropics into temperate seas are animated by a more rapid movement towards the east than those amidst which they flow. They deviate, in consequence, in an easterly direction, and when the returning current reaches the polar sea it seems to come from the west. Thus the grand circuit of the waters is completed in each hemisphere. The Atlantic and the Pacific have each their double circulatory system, formed of two immense eddies united in the torrid zone by a common equatorial current. As regards the Indian Ocean, being bounded on the north by the continent of Asia, it has but one simple current, which turns incessantly in its vast basin between Australia and Africa. As a whole, these ocean rivers recall by their distribution the divisions of the land. The two great whirlpools of the Atlantic correspond to the two continents of Europe and Africa; the huge eddies of the Pacific have a binary division analogous to the two continents of America; and the current of the Indian Ocean reminds one of the enormous mass of Asia, which alone fills half the northern hemisphere.

CHAPTER VIII.

THE GULF-STREAM.—INFLUENCE OF THIS CURRENT ON CLIMATE.—ITS IMPORTANCE TO COMMERCE.

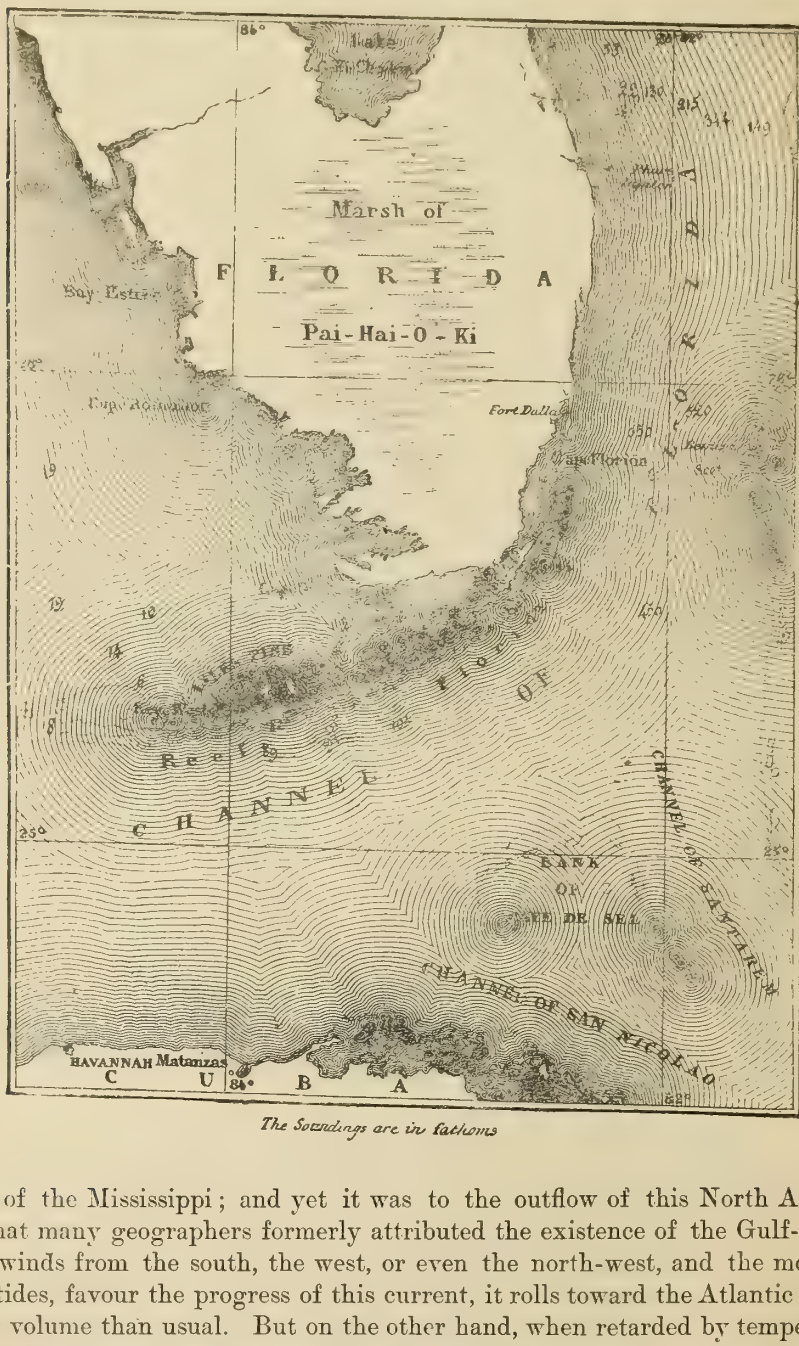
OF all the oceanic rivers, the best known to us is that part of the north Atlantic current, which the English and the Americans have named the Gulf-stream, because it makes a long circuit in the Gulf of Mexico before reaching the ocean. In the year 1513 the Spaniards Ponce de Leon and Antonio de Alaminos knew of the existence of this current; and six years later Alaminos, setting forth from the Straits of Florida, allowed himself to be carried by the water into the open sea, and thus discovered the great circular route which ships have now to follow in order to return speedily to Europe. Since the time of Varenius, who attempted to describe the Gulf-stream, of Vossius, who traced its immense circuit on a map, Franklin and Blagden, who were the first to explore it scientifically, this current has been studied by numerous geographers. Without doubt, there is no marine current which merits to be better known in all its details; none has been of more importance in the commerce of nations or exercises a greater influence upon the climate of the North-West of Europe. It is to the Gulf-stream that the British Isles, France, and the neighbouring countries owe in great part their mild temperature, their agricultural wealth, and in consequence a very considerable part of their material and moral power. Its history is almost identical with that of the entire North Atlantic Ocean, so important is its hydrological and climatic influence.

The celebrated Maury devotes the most important part of his classical work on the "Geography of the Sea" to the Gulf-stream. It "is a river in the ocean; in the severest droughts it never fails, in the mightiest floods it never overflows. Its banks and its bottom are of cold water, whilst its current is of warm. There is in the world no other such majestic flow of waters. Its current is more rapid than the Mississippi or the Amazon, and its volume a thousand times greater." Such is the epic language in which Maury's fine work commences.

After having made the tour of the Caribbean Sea and the Gulf of Mexico in six months, after having driven back upon the shores of Alabama the muddy waters of the Mississippi which border its dark blue waves, the Gulf-stream follows the northern coast of Cuba, then turns the southern point of Florida, and penetrates the strait which separates the American continent from the islands and banks of Bahama. Swelled by the mass of water which the great equatorial current sends directly through the straits of the archipelago, and above all by the old channel of Bahama, the Gulf-stream flows straight to the north, pressing through the ocean

like a river nearly 37 miles wide, and of an average depth of 200 fathoms. Its speed is great, even equalling tha of the principal rivers of the world, being sometimes from about $4\frac{1}{2}$ to 5 miles an hour; but usually it is about $3\frac{1}{2}$ miles. The mass of water discharged by the current may, therefore, be estimated at nearly 45 millions of cubic yards per second, that is to say, at 2000 times the mean dis-

Fig. 23.—Channel of Florida.



The Soundings are in fathoms

charge of the Mississippi; and yet it was to the outflow of this North American river that many geographers formerly attributed the existence of the Gulf-stream! When winds from the south, the west, or even the north-west, and the movement of the tides, favour the progress of this current, it rolls toward the Atlantic in much greater volume than usual. But on the other hand, when retarded by tempests that blow from the north-east, it pours a much smaller quantity of water into the ocean.

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When thus checked, it swells, rises, spreads with fury over the low lands that border it, ravages vast tracts, and causes whole islands to disappear. At its embouchure into the ocean, this marine river resembles those streams which flow through continents: it erodes on the one side, while it deposits alluvium on the other. And doubtless the Bahama Islands, which are scattered through the sea to the east of the Gulf-stream, and the *Keys*, or rocks developed on the north in a long range, rest on a foundation of submarine banks formed in part by the deposits of this grand river.

On emerging from the Strait of Florida the Gulf-stream expands and spreads over the Atlantic, but at the same time its depth becomes proportionately less considerable. Whilst the strata of cold water which serve as its banks retire on each side and allow it to spread over a greater breadth, the cold bed of water which bears it and over which it flows, as terrestrial rivers glide over beds of rocks, gradually approaches nearer the surface. At Cape Hatteras the depth of the current is about 120 fathoms, and its speed does not exceed three miles per hour; but it is twice as wide when it emerges from the Strait of Florida, and spreads over a space of about 78 miles. The thickness of this powerful stream of warm water is constantly diminishing, and when it has crossed the Atlantic it is only a superficial sheet. But even then it covers an immense extent, reaching from the Azores to Iceland and Spitzbergen.

The soundings taken since 1845 by the officers of the Coast Survey of North America, prove that the Gulf-stream flows along the coast of the United States at some distance from the land. The slight inclination of the low lands of Georgia and Carolina is continued under water till the lead reaches a depth of about 50 fathoms. The bottom then sinks rapidly, and forms a long valley parallel to the shore of the United States and the chalky walls of the Appalachians; it is in this valley, hollowed to the east of the submarine basement of America, that the waters of the Gulf-stream flow. Owing to the rotatory motion of the globe, and probably also to the general direction of the coasts, the current follows a constant direction to the north-east, and does not touch any of the advanced points of the continent. Off New York and Cape Cod it deviates more and more to the east, and ceasing to follow at a distance the American coast-line, rolls across the open Atlantic towards the shores of western Europe. Thus, as Maury says, if an enormous cannon had force enough to send a bullet from the strait of the Bahamas to the North Pole, the projectile would follow almost exactly the curve of the Gulf-stream; and gradually deviating on its way, would reach Europe from the west.

Between the 43rd and 47th degrees of north latitude, in the neighbourhood of the Bank of Newfoundland, the Gulf-stream, coming from the south-west, meets on the surface of the sea the polar current discovered by Cabot in the year 1497. The line of demarcation between these two oceanic rivers is never absolutely constant, but varies with the seasons. In winter, that is to say from September to March, the cold current drives the Gulf-stream towards the south; for during this season all the circulatory system of the Atlantic, winds, rains, and currents, approach more nearly the southern hemisphere, above which the sun travels. In summer, that is to say from March to September, the Gulf-stream in its turn resumes its preponderance, and forces back the line of its conflict with the polar current more and more towards the north. Thus the great river undulates here and there over the seas, and according to the graceful expression of Maury, waves like a pennon in the breeze. But it is probable that the advance of the two opposing currents is often modified only in appearance, in consequence of the

superficial expansion of cold or warm water. The Bank of Newfoundland, that enormous plateau surrounded on all sides by abysses five to six miles deep, is undoubtedly due in great part to the meeting of these two moving liquid masses. On entering the tepid waters of the Gulf-stream the icebergs gradually melt and let fall the fragments of rock and loads of earth which they bear, into the sea. The bank which rises gradually from the bottom of the ocean is a sort of common moraine for the glaciers of Greenland and the polar archipelago.

After encountering the waters of the Gulf-stream, those of the arctic current cease in great part to flow on the surface, and descend into the depths, in consequence of the greater weight which their low temperature gives them. The direction of this counter-current, exactly opposite to that of the Gulf-stream, is demonstrated by the icebergs, which the warm breath of temperate latitudes has not yet melted, which travel towards the south-east, directly against the superficial current, which they divide like the prow of a ship. More to the south, we recognize the existence of this concealed current only by means of sounding apparatus, the cold waters serving as a bed to the warm river flowing from the Gulf of Mexico; it descends lower and lower as far as the Straits of Bahama, where the thermometer discovers it at a depth of 220 fathoms.

Nevertheless a part of the waters of the polar current remains at the surface of the sea; and, gliding along the eastern coast of the United States as far as the point of Florida, gives to the Gulf-stream by contrast very sharply defined limits. Generally the cold water coming from the Arctic Sea possesses sufficient force to compel the current from the Gulf to bend sensibly towards the south, and to oppose an insurmountable barrier to it in the other direction. The warmest and most rapid part of the Gulf-stream, which forms precisely the left or western side of the current, is found in immediate juxtaposition to a sheet of cold water, which spreads in an opposite direction between the Gulf-stream and the American shores. This counter-current, which interposes the waters of the Icy Sea between the coast of Carolina and the warm river flowing from the Gulf of Mexico, bounds the Gulf-stream like a wall of ice. Sometimes the line of demarcation between the two liquid masses is so precise that it is appreciable to the sight, and the exact moment when a ship leaves one current, to cleave the other with its prow, may be distinguished. The water of the Gulf-stream is of a beautiful azure, that of the counter-current is greenish; the first is saturated with salt, the latter contains it in a much less proportion. The one is tepid, the other cold, and the thermometer, when plunged alternately in the two liquids, instantly marks the difference of temperature. On the boundary line of the currents, the friction of the two masses of water flowing in opposite directions produces a series of eddies, whirlpools, and short waves, which give to these ocean-rivers an aspect similar to that of continental rivers. Sometimes one can even hear like a dull roaring, the noise of the waters contending on the surface of the sea. Floating plants and other fragments are whirled round on the ever-changing boundary of the two contending streams.

The Gulf-stream, like all other currents, finally mingles with the sea, and thus tends to equalize the proportion of salt and all other substances contained in the liquid mass. The normal salinity of the Caribbean Sea is from 36 to 37 thousandths, except in the neighbourhood of the mouths of great rivers. After having received the fresh waters of the Mississippi and the visible and subterranean rivers of Florida, the Gulf-stream does not contain quite 36 thousandths of saline substances; but this is gradually increased as it advances towards the north. Off Newfound-

land, where the waters of the St. Lawrence and many other rivers, as well as the melted ice, fogs, and heavy rains, have rendered the waves of the sea more fresh, the Gulf-stream contains less than 34 parts in 1000 of saline matter, but it gradually increases the proportion to 35 thousandths as it shapes its course towards the coasts of western Europe, and the polar regions. The currents of cold water which serve as its bed are all less rich in saline substances, as Forchhammer and other chemists have proved. But in consequence of the incessant mixture of the waters, an equalization of saltness between the currents is produced in the various latitudes.

The Gulf-stream, properly so called, mingles with the volume of tepid water, which, coming from the equatorial regions, sets northwards in the direction of the cold currents from the pole. The whole of the immense body of tepid water thus formed is usually called the Gulf-stream ; but this is an abuse of language, because the true Gulf-stream merges like a feeble tributary in the vast moving sea developed by the tropical current. In fact, Florida Passage is far too narrow a channel to admit a stream large enough to spread out from shore to shore of the North Atlantic ocean, occupying between the Newfoundland Bank, Iceland, and Scandinavia a superficial area of at least 1,600,000 square miles, and penetrating so deep that the sounding line still meets it 830 fathoms from the surface. Even admitting that the normal discharge through Florida Passage may be calculated at about 1380 million cubic feet per second, this saline stream would take no less than nine years to fill the whole region at present occupied by the tepid waters of the North Atlantic Ocean.

Another effect of the Gulf-stream, no less important in the economy of our planet, is that which it accomplishes in concert with the south-west winds, on the climate of western Europe. While rotating in the Gulf of Mexico, as in an immense cauldron, the waters of the current are gradually heated; when they escape through the Strait of Florida to enter the ocean, their temperature is not less than 86° F. and exceeds by about 4° F. the natural heat of the neighbouring beds of water. The waters of the Gulf-stream lose their warmth but slowly, and during winter they often have, off Cape Hatteras and the bank of Newfoundland, a temperature exceeding by 21° or 28° F. that of the rest of the Atlantic under the same latitudes. When the Gulf-stream meets the polar current, the former has still a temperature of 36° or even 45° F., whilst, even at a distance of some hundreds of miles from the coasts of Labrador, the latter is sometimes found to be below freezing-point (24·8° F.) ; thus, in defiance of latitude, the waters of the tropics and of the icy zone are brought into juxtaposition. In its advance towards the north, the upper strata, which in consequence of radiation have become colder than the subjacent layers, descend to a greater or less depth in the mass of the current and are replaced by the warmer and lighter water, lying immediately below. Thus a constant alternation of position is produced in the liquid strata of the Gulf-stream, and one may remark in consequence, in crossing the whole breadth of the current, a series of parallel bands of unequal temperature. In each of these bands the warm water rises by turns to the chilled surface of the sea. It is a remarkable fact, that if the Gulf-stream did not flow as it does in a bed entirely composed of cold water, but moved along the very bottom of the ocean, it would rapidly lose its high temperature, and would cease in consequence to be a source of heat for western Europe. In fact, the earth being a better conductor of heat than the water, the warm waters of the current would communicate their temperature to it, and would finally lose their whole store. But the cold waters of the polar current, being

interposed between the bottom of the sea and the waters of the Gulf-stream, serve as a protecting screen to the latter and hinder their refrigeration. It is by such contrasts as these that the harmony of the world is established.

The quantity of heat which the Gulf-stream carries towards the northern regions forms a very considerable part of the caloric stored up in its waters under the tropics. The cetaceans, fish, and other inhabitants of the torrid zone follow the course of the Gulf-stream without perceiving that they have changed their country, and often push their adventurous voyages to the Azores and even to the coasts of Iceland; the southern birds mount also towards the north in the warm stream of air reposing on the current. The animals of northern seas, on the contrary, are kept prisoners in the glacial ocean, and the true whales, says Maury, recoil before the Gulf-stream, as before "a barrier of flame." The total warmth of the current would suffice, if it was centred in a single point, to fuse mountains of iron and cause a river of metal as mighty as the Mississippi to flow forth. It would suffice also to raise from a winter to a constant summer temperature, the entire column of air which rests on France and the British Isles. But, though it is spread over enormous spaces to the west and north of Europe, the Gulf-stream does nevertheless exercise a preponderating influence upon the climate of this part of the Old World. Owing to the warmth of its waters the lakes of the Faröe and Shetland Isles never freeze during winter; Great Britain is enveloped in fogs, as in an immense vapour-bath, and the myrtle grows on the shores of Ireland, the "emerald isle of the seas," under the same latitude as Labrador, that land of snow and ice. In green Erin, an island privileged in so many respects, the western coasts (the first land which the Gulf-stream encounters after crossing the Atlantic) enjoy a temperature two degrees higher than that of the eastern coasts. In spite of the path of the sun, it is on an average as warm in Ireland under the 52nd degree of latitude, as in the United States under the 38th degree, or about 1025 miles nearer the equator.

The Gulf-stream, which conveys the tropical warmth to the temperate countries of Europe, very often serves as a high-road for tempests. Hence the names of *weather-breeder* and *storm-king*, which have been given to this current. The movements of the atmospheric ocean and those of the ocean waters occur in such complete parallelism that one would be tempted to regard them as one and the same phenomenon in the *ensemble* of aërial and marine currents. Thus the Gulf-stream seems to be for the winds, as it really is for the waters, the great medium between the Old and New Worlds. It carries to the seas at the north of Europe the salinity of the Gulf of Mexico; it bears with it the warmth of the tropics for the advantage of the temperate regions, and marks the track which the torrents of electricity, disengaged by the hurricanes of the Antilles, follow. It is indeed the great serpent of the Scandinavian poets, which uncoils its immense folds across the ocean, and from its head, which it waves here and there over the shores, wafts a gentle breeze, or pours forth storm and lightning.

The Gulf-stream crosses the Atlantic with a mean speed of about 24 miles a day, as has been ascertained either by direct measurement at different parts of the ocean, or by means of notes, which having been thrown overboard in bottles carefully closed, have floated for weeks or months at the will of the waves, and then been fished up in other latitudes or found on some seashore. In their long passage, the deep waters of the marine river of America transport scarcely any other alluvium than the living frustules of animalculæ, which fill the tepid waters of the current and are constantly falling in a kind of snow to the bottom of the sea. But here and there on the surface of the Gulf-stream float trunks and branches of

trees, which are finally thrown on some coast of Europe, and even on the island of Spitzbergen. It was these remains which our ancestors of the middle ages believed to come from the fabulous island of St. Brandan or from Antilia, and which furnished matter for thought to daring navigators like the great Columbus. Seeds carried from the New World by the current have found a favourable soil on the shores of the Azores, and although many thousands of miles from their native land, have germinated and borne fruit. Often too the waves of the Gulf-stream bring to Europe the broken products of human industry and the timber of wrecked ships. During the Seven Years' War, the mainmast of an English man-of-war, the *Tilbury*, which had been burnt near St. Domingo, was found on the northern coasts of Scotland. In the same way a river-boat, laden with mahogany, was once even driven to the Faröe islands. The remains of ships wrecked in the latitude of Guinea have been brought to the coast of the British Islands, after having twice crossed the ocean in opposite directions; and Esquimaux have often been carried by the waves to the Orkneys.

It is rather difficult to lay down the precise route of the Gulf-stream in the seas of western Europe, because of the enormous width of its moving expanse. One may say that in reality it stretches over the whole ocean, from the Azores to Spitzbergen; but having lost in its onward impulse in proportion as it has gained in extent, it is modified and turned aside in its course by a host of local circumstances and the varied configuration of the coasts of Europe. Only that part of the current which flows to the north of Ireland and Great Britain maintains its original direction. It bathes all the islands between Scotland and Iceland, warms the coasts of Norway, even in Lapland it melts the ice at the port of Hammerfest, and then continues its course in the Polar Sea towards Spitzbergen. Thus, as the Swedish expedition in 1861 ascertained, the current makes itself felt even on the northern shores of the latter archipelago; for the seeds of a plant from the Antilles (*Entada gigalobium*) were found on the shore of Shoal-Point, lying at more than eighty degrees north latitude. Indeed it is certain that the current even bathes the western coasts of Novaia-Zemlia, for bottles that came from a glass factory in Norway, and the nets of Scandinavian fishermen, have been found there.

It has been ascertained that during a former geological epoch, when the south coast of the Bohuslän district, north of Göteborg, was 30 feet lower than at present, the stream from the Antilles already washed the Swedish seaboard. This fact is proved by some grains of the entada plant, which were found in a peat bog standing 30 feet above the present level of the surrounding waters. The Gulf-stream also penetrates into the White Sea, first setting along the east coast, and afterwards bathing the west side after diffusing a relatively higher degree of temperature over the southern shores of that marine basin.

How then do these waters, which spread in such a vast sheet over the surface of the Icy Sea, continue their progress towards the Pole? Here hypothesis commences, since no navigator has yet been able to explore these latitudes and study their hydrological laws. But we know at least in part the origin of the polar current, and by the direction which this mass of water takes may be indicated that which the Gulf-stream itself must follow. Along all the northern coasts of Siberia, as Wrangel and other explorers have told us, a current of cold water flows from east to west. Encountering on its way the large island of Novaia-Zemlia, it covers the strand and rocks with enormous quantities of ice, which render the island quite uninhabitable and close the straits to navigation. Arrested by this barrier the waters of the glacial current are forced to bend to the north, and flow

in a north-westerly direction towards Spitzbergen, round the northern archipelago of which they finally turn in order to enter the seas around Greenland. It is here that they begin to take a direct road towards the equatorial seas; and all the navigators who have ventured to the north-west of Iceland have recognised the existence of this stream, flowing along the coast-line as far as Cape Farewell. Its average speed, according to Graah and Scoresby, is from 3 to 4 miles a day.

To the south of Greenland the lessened sheet of the Gulf-stream must meet this transverse current, and doubtless, in consequence of the greater weight which its stronger proportion of saline substances imparts to it, it plunges into the depths and is changed into a submarine current, which finishes by mixing completely with the cold waters of the northern seas, and flows back at last towards the equator in an opposite direction to that which it at first pursued. Thus the river of warm water from the Gulf of Mexico feeds by its incessant contributions the polar counter-current, and the great circuit is established between the zone of heat and that of ice. Perhaps, too, the reflux of the Gulf-stream is partially accomplished, under the pressure of water from the north, by an abrupt turn. This would explain the strong salinity of 35 thousandths, which Forchhammer found in the waters of the polar current to the east of Greenland.

It is not only in the wide extent of the North Atlantic, from Novaia-Zemlia to Iceland, that the Gulf-stream takes a submarine course; the same is the case, it appears, in Baffin's Bay to the west of Greenland. In fact, from Cape Farewell to eight degrees farther north the existence of a coast-current has been ascertained, which carries the ice in an exactly contrary direction to that of the current, which follows on the west the coasts of Labrador, and which serves as a high road for the fragments of the ice-fields. This current was formerly considered as the continuation of the one which flows along the eastern coast of Greenland from north to south, and which would thus have abruptly turned round Cape Farewell. But it is much more natural to think that the polar current continues its route directly towards the great centre in the tropical seas. In this case, the current on the western coast of Greenland would be simply a branch of the Gulf-stream, which is rendered almost certain by its waters being comparatively warm. The sea very seldom freezes on the shore which it bathes, and the climate there is on an average 9° F. warmer than on the coast looking towards the east. Towards the 78th degree of latitude, this river-like current completely ceases, and it is undoubtedly there that it becomes submarine, perhaps to flow on the surface again in the open Sea of Kane.

On the other hand, if in the icy seas the various branches of the Gulf-stream change into smaller counter-currents, the polar currents do the same more to the south, and become the bed for the waters which flow to the north. These contain, it is true, more saline substances, but they are also warmer; rendered heavy by the salt, they are lightened by their high temperature, so that a slight difference of warmth or of salinity can modify their equilibrium and make them change their position with the polar current. In the temperate seas, where they are still warm and strongly saline, they flow on the surface; but sink on the contrary in the icy seas, where they are chilled or where the admixture of salter water is effected. This explains the intersection of the currents. To the north of Spitzbergen and Novaia-Zemlia, the Gulf-stream is a submarine sheet; to the south of Iceland it is the waters from the pole which flow below. Not far from the Faröe Islands the sounding-lead can even indicate the direction followed by the icy counter-current, owing to the layer of volcanic remains, which have been brought from the coasts

of Iceland, and spread over a space of 25 degrees of longitude between the 47th and 52nd degree north latitude. This hidden river must flow, at least in certain places, on the very bottom of the sea, for various soundings taken by McClintock to the south-east of Iceland, show that all the light detritus has been swept away by its waters.

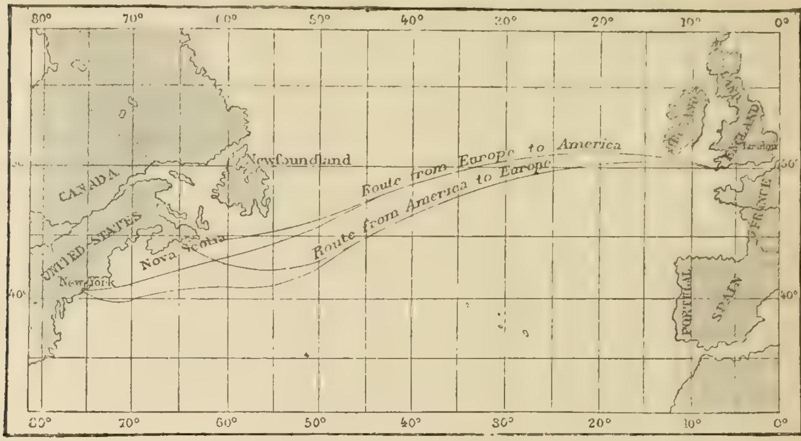
If the Gulf-stream throws out various branches towards the north, which contribute to form the vast circumpolar whirlpool, in the same way another branch flowing towards the south goes to swell the equatorial current. This offshoot of the Gulf-stream, of which one branch penetrates into the Bay of Biscay and forms the coast-current called Rennell's, flows along the coasts of the Iberian peninsula, follows the outline of Africa to the south of the Canaries and Cape de Verde Islands, where lateral counter-currents occur, and enters the great marine river which moves the waters from east to west, "following the course of the heavens."

Thus is completed the immense circuit of the Atlantic, in the centre of which the sea meadows of wrack extend in clusters like an archipelago. It is owing to this perpetual circuit that navigators in sailing vessels have been able to reach the New World from western Europe. If Columbus had not made use of the semi-circular current which flows from the coasts of Spain to the Antilles, he certainly would not have discovered America. If the pilot Alaminos, and, since his first voyage, the greater part of the navigators returning from the Antilles and United States, had not, either without knowing it, or else well understanding the cause, followed the course of the Gulf-stream, the coasts of America would have remained practically far more distant from Europe than they really are. The colonies, now become so prosperous as independent republics, would be still in deplorable isolation; and civilization would have been greatly retarded, or even completely arrested, for want of new impetus. As to commerce, properly so called, one can judge of the influence exercised upon it by the movement of the waters of the Atlantic, when one examines on a map the position of the great centres of trade. Havannah and New Orleans, two principal markets of the Antilles and Mississippi States, are, so to say, at the source of the Gulf-stream. New York is situated facing the principal bend of this current, at the spot where the vast river flowing from the Antilles bends towards Europe. Finally, Liverpool, among so many other considerable ports washed by the Gulf-stream on its arrival at the coasts of the Old World, is the one which is most directly in the path of its waters.

When Franklin discovered, in 1775, that the mariner has only to plunge a thermometer in the water of the Atlantic to discover if he is sailing over the Gulf-stream or outside its course, the illustrious savant immediately perceived the importance of this fact for navigation. He then thought for a long time he must conceal it, from a fear that the English government, then at war with the American colonies, would profit by this discovery to send ships and men more rapidly against the revolted provinces. After the definite establishment of American Independence, no peril of this kind being any longer to be feared, all navigators were enabled for the future to know precisely the high road which they had to follow in the open sea to reach Europe most expeditiously from America, and what particular line to avoid in order to effect the journey in an opposite direction. Towards the middle of the last century, the whalers of Nantucket and the skippers of Rhode Island had already from experience come to choose two different routes for going and returning. In order to "descend" on England they allowed themselves to be carried with the Gulf-stream, and on their return crossed this current at the banks of Newfoundland, and "mounted" the Arctic

counter-current ; on these voyages they distanced vessels from other seaports, on an average, by 74 miles per day. The progress of navigation permits us now to utilize the impelling force of the currents of the North Atlantic far better than the sailors of Providence could. The normal duration of the passage has been reduced to half. Eight weeks were formerly reckoned for a voyage from England to the United States; now four weeks suffice for sailing vessels, and some have even

Fig. 24.—Route of Steam-packets, after Maury.



made the journey in seventeen days only. Steamers, which also have a double route too, in order to avail themselves of the current, accomplish the passage in nine or ten days. For commerce, civilization, and the brotherhood of peoples, such a result is not less important than if the continents themselves were shifted, so as to reduce by three-quarters the width of the ocean which separates them.

CHAPTER IX.

CURRENTS OF THE SOUTH ATLANTIC AND THE INDIAN OCEAN.—DOUBLE EDDIES OF THE PACIFIC OCEAN.

THE circuit of the waters which occurs to the south of the equator, in the southern basin of the Atlantic, is much less known than that of which the Gulf-stream forms a part, but all that has been observed of it by navigators proves that the movements of the liquid mass are analogous in the two hemispheres. A current of cold water, coming from the Antarctic seas, dashes against the Lagullas Bank, to the south of the African continent, and divides into two branches, one of which re-enters the Indian Ocean, while the other flows along the western coast of Africa, penetrates into the Gulf of Guinea, and, in consequence of the motion of the earth, bends towards the west in a wide semicircle. To the south of the Cape Verde Islands, the waters coming from the southern seas join those which flow from the Icy Sea of the north, and uniting into one river of 500 to 1000 miles wide, move slowly in the direction of South America and the Antilles. The greater mass of water approaches the continent to the north of Cape St. Roque, the advanced promontory of Brazil, and flowing to the north-west along the coasts of Guiana and Columbia, enters the Caribbean Sea, there to form the Gulf-stream. A less considerable fraction of the equatorial current bends to the south of Cape St. Roque, and follows the Brazilian coast-line to the south-west. But in descending towards latitudes nearer and nearer the southern pole, the warmer current from the equator incessantly gains on the rotatory movement of the earth; consequently, it bends more to the south than to the south-east, and forming a sort of Gulf-stream in an opposite direction, it strikes the polar current to the east of the Falkland Isles, whose position in the southern hemisphere corresponds to that of Newfoundland in the northern hemisphere. There the warm current, after having deposited drift-wood, taken from the Brazilian coast, on the shores of the Falkland Islands, sinks below the lighter strata of the glacial current; while the latter directs its course to the north-east, towards St. Helena, where it joins the great equatorial river. The whole circuit is accomplished in a period which may be estimated at about two or three years.

Dissimilar, and often contradictory, observations recorded by various navigators who have studied the phenomena of the waters in the South Atlantic, seem to put it beyond doubt that the currents of this basin have not the same regularity of course as those of the Northern Atlantic. It frequently happens that the water does not flow in the direction indicated on maps, or even tends in an opposite direction to the normal movement. The reason of this difference between the two

basins is quite natural. While the North Atlantic is a very regular sea in its general form, bounded on each side by almost parallel shores, the marine area lying between Africa and South America expands very widely from the coast of the southern polar land. It may be considered simply as a gulf of the great ocean, which extends around the globe to the south of the extremities of the three southern continents. As a consequence of this irregular disposition of the coasts, the variations from the normal circumstances of the waters cannot fail to be very great. The cold waters from the Antarctic Pole, charged with fragments of ice-fields and icebergs, flow, it is true, with a continuous motion to replace the vapours which rise incessantly from the equatorial Atlantic. But the regular play of the currents is modified now at one point now at another, according to the greater or less activity of evaporation in those parts of the sea. Besides, the changing coast-winds which blow alternately from the ocean to the land and from the land to the ocean, impress their varying movements on its surface.

The Indian Ocean has likewise its great circuit of water. There too the mass of fluid, chilled by its sojourn in the icy zone, is incessantly flowing towards the equator, in order to fill up the vacancy produced by the annual evaporation of 13 to 16 feet. It flows along the western coast of Australia, and afterwards unites with the waters that come from the Pacific Ocean, through Torres Straits and the East Indian archipelago. But there the regular current seems to lose itself; and we only see in the Gulfs of Bengal and Oman, marine rivers changing their course with the monsoons. Nevertheless it must really be that the general movement of the waters is continued from the east to the west around the vast basin, for on the eastern coast of Africa a current of warm water, incessantly supplied by the seas which bathe Hindostan and Arabia, flows to the south-west, and under the name of the Mozambique current, passes between the island of Madagascar and the continent, touches the edge of the great submarine bank of Lagullas, and spreads into the Antarctic Ocean, after having mingled a part of its waters in the great whirlpool of the Atlantic. At the part where it is narrowest, the Mozambique current is almost as rapid as the Gulf-stream, and moves with a speed of about 4½ miles an hour. In the centre of the eddy in the waters of the Indian Ocean, as in the North Atlantic, whole meadows of seaweed spread over the calm waters. At the same time, the direction of the surface currents along the coast is modified by the influence of the monsoons. During the north-east monsoon the waters set in the direction from north to south along the Coromandel coast, and round the island of Ceylon eastwards. But during the south-west monsoon the stream is, on the contrary, directed from north to south along the Malabar coast.

The circuit of the currents commences in the great Pacific Ocean in the same manner as in the other basins. An immense river of cold water of unknown breadth strikes the island of Magellan, at the south of America, and divides into two partial currents, one of which, penetrating into the Atlantic to the east of the Falkland Isles, where ice never comes, joins in the great round of waters between Africa and Brazil, while the other flows directly to the north along the coasts of Patagonia, Chili, and Peru; this is Humboldt's Current, thus named after the celebrated traveller who first recognized its existence. It carries with it large icebergs often laden with stones and fragments that have fallen from the Antartic mountains, and by the coldness of its waters produces a remarkable lowering of the temperature in all the countries whose shores it bathes. This liquid mass, which has a depth of no less than 670 fathoms on the coast of Chili, gives to the vegetation of the country a remarkable analogy with that of St. Helena, which at

SURFACE CURR

Ocean

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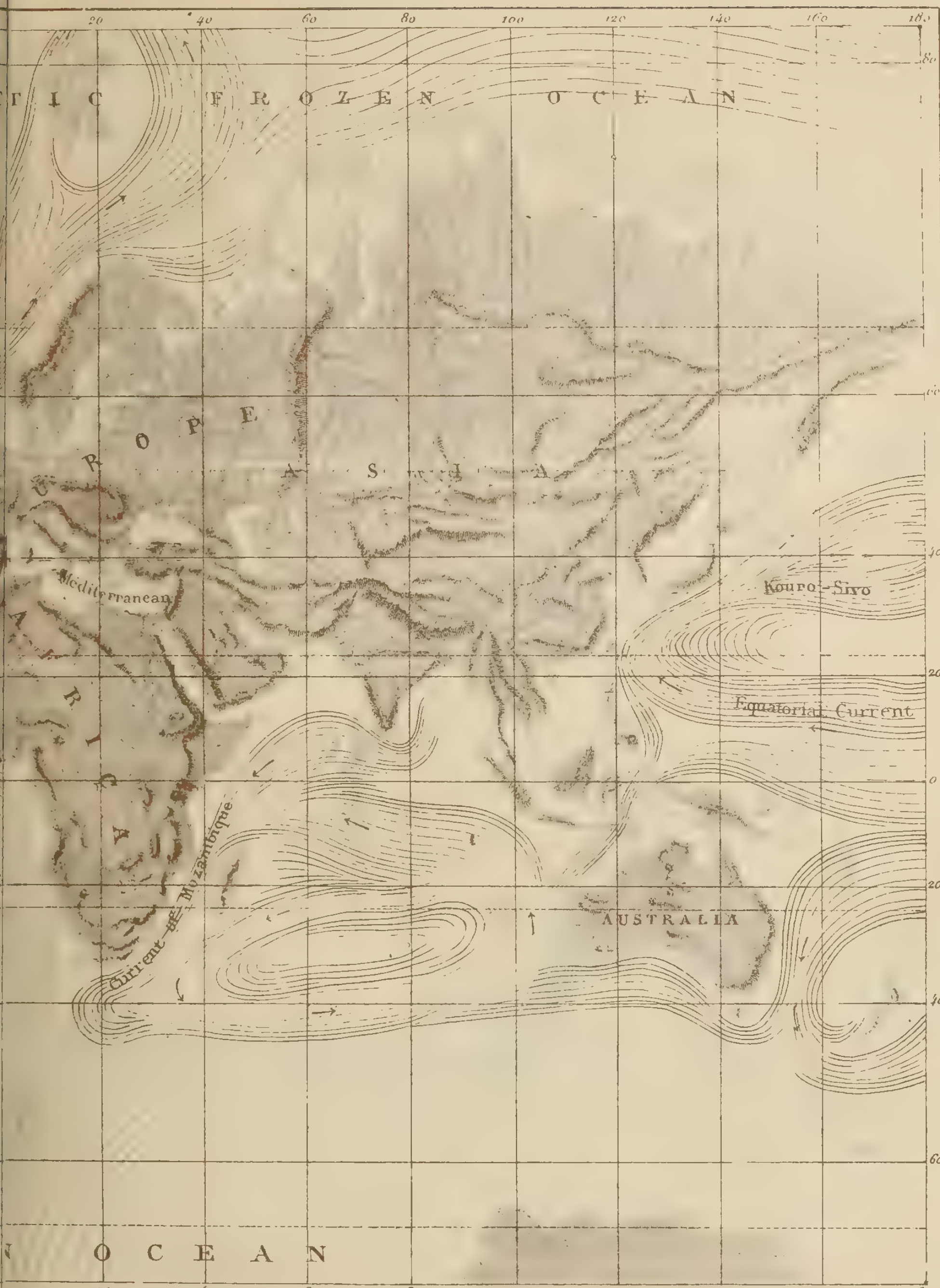
RNTS OF THE OCEAN. PL. VI.



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a distance of 4000 miles is washed by another branch of the Antarctic current. Humboldt and Duperrey state, that off the coasts of Callao and Guayaquil—that is to say, in one of the driest climates and most exposed to the rays of the sun—the current is on an average at from 59° to 60° F., while the adjacent seas are about twenty degrees warmer. Not a branch of coral can take root on the rocks and shores washed by this current of cold water: the polar current changes everything on its passage—the flora, fauna, climate, and even the history of mankind. If the air was not constantly refreshed by the contact of cold water coming from the pole, Peru, which is so rarely watered by rain, would be transformed into another desert of Sahara, and human life would become almost impossible there. By this current, too, the distances are notably diminished, and Valparaiso, Coquimbo, Arica, Callao are, in reality, less distant from Europe than they appear on the map; for after having rounded Cape Horn, the ships sailing along the western coasts of South America are carried about 15 to 20 miles a day by this current.

Widening more and more on the side of the open sea, Humboldt's Current ends by abandoning the coast-line, and bending towards the west, to mix its waters with those of the equatorial current tending from east to west across the Pacific. This liquid moving mass is undoubtedly the most powerful oceanic river of our planet. According to Duperrey, it has a mean width of no less than 3500 miles, from the twenty-sixth degree of south latitude to the twenty-fourth degree of north latitude, and on its immense journey in a straight line round the world, it traverses from 130 to 140 degrees of longitude; that is to say, more than a third of the circumference of the globe. Its average speed is, like that of Humboldt's Current, about 19 miles per day, but in certain places, according to the seasons, an advance twice as rapid has been ascertained. What the quantity of this enormous mass of water can be that is thus displaced from one end of the sea to the other, is unknown; for it would be first necessary to know the mean depth of the current, but this the sounding-lead has not yet discovered. It is only known that at the point where the water from the pole turns towards the west, to enter the great equatorial stream, it proceeds *en masse* in one direction, with a depth of not less than a mile.

In the midst of the innumerable islands which are scattered over the Pacific, the general regularity of the great current is frequently disturbed, at least on the surface, in consequence of evaporation, rains, and even by the incessant labours of the coral-building zoophytes, which in various ways disturb the equilibrium of the ocean.

But under the threefold influence of the terrestrial rotation, the trade-winds, and the great tidal wave which is propagated from east to west across the ocean, the quantity of water moved each day towards the west is certainly several tens of thousands of cubic miles. The only anomaly in this prodigious movement of the waters of the Pacific which seems inexplicable is the existence of an oceanic river flowing in an opposite direction to the principal current. This reflux has been observed to the north of the equator over a mean breadth of upwards of 300 miles; elsewhere its speed is variable, and its advance is not always in the direction of due east. In the absence of measurements and positive experiments which permit us to give an exact account of the progress of this counter-current in the different seasons, several hypotheses have been suggested to explain its origin. The common opinion is that it is masses of water turned aside on their course and thrown back by submarine plateaux. Nevertheless it is much simpler to admit that this is a normal phenomenon, for in the Atlantic Ocean it has also been established that

some lateral eddies tend in an opposite direction from the great liquid mass flowing from east to west.

When it has arrived at the end of its voyage across the Pacific, the equatorial current must of necessity change its direction. A portion of its waters, driven now in one direction and now in another by the monsoons which succeed one another on the borders of the continents of Asia and Australia, flows into the Indian Ocean by the shallow straits of the East India Islands. But the greater mass of the current is thrown back either to the south or to the north, by the resistance of the shores against which it dashes and breaks. The half of the current which strikes the coast of Australia diverges towards the south, and flows in the direction of the Antarctic lands. It thus flows in the opposite direction to the polar current, which it finally encounters to the south of New Zealand, and plunges beneath its colder waters, which by their freshness are rendered lighter. To the east and north-east the current from the Antarctic seas completes the enormous circuit described by the waters in the southern basin of the Pacific.

The other half of the equatorial current, diverted by New Guinea, the Philippines, and that long barrier of islands lying to the east of China, bends gradually towards the north and flows along the outer coasts of Japan. It is the Gulf-stream of the Pacific Ocean, called also Tessan's Current, after the navigator who revealed its existence to the savants of Europe. But for centuries, and perhaps thousands of years, the Japanese have known and prized it highly for their coast navigation. They give it the name of Kuro-Sivo, or "Black River," doubtless because of the deep blue of its waters. Less rapid than the Gulf-stream, its advance is nevertheless on an average more than $1\frac{1}{4}$ mile per hour, and in many places very much exceeds this speed. Off Tokio its mean temperature is 75·2° F., that is to say, about 10° to 12° F. higher than the still waters beside it. Furthermore, the Kuro-Sivo, like the Gulf-stream, is composed of liquid bands of unequal temperature flowing beside each other like two distinct rivers in the same bed.

In passing the largest island of Japan, the Black River, obedient to the impelling force which the rotation of the earth has communicated to it under tropical latitudes, already commences to bend towards the north-east, and, spreading over a vast extent, loses in depth what it gains in surface. To the north of Japan, it meets obliquely a current of cold water emerging from the Sea of Okhotsk, to replace in part the void caused by the evaporation in the equatorial seas. Thick fogs, similar to those of the Banks of Newfoundland, rest above the spot of contact between the warm and cold waters. Shoals of fish, the object of pursuit to fishermen, people this maritime zone, which serves as a limit between the two currents, and where the mass of animalculæ and remains brought from the tropics is joined to those which are conveyed in the waves coming from the north. Still, the phenomena presented by the meeting of the two currents have not the same grandeur in the North Pacific as under the corresponding latitudes of the Atlantic; for the mass of water flowing from the Sea of Okhotsk is relatively less considerable, and the opening of Behring's Straits, 31 miles wide and 50 fathoms deep, is of too small dimensions to allow much water from the icy ocean to penetrate into the Pacific. Only small coast-currents, carrying the pines and firs from the shores of Siberia, and rounded ice-floes from along the two coasts, cross from one sea to the other. In summer the current which comes from the north, both on the eastern and western bank of the strait, is only a superficial current. On the other hand, the slight portion of the waters of the Black River which passes beyond the range of the Aleutian Islands, to enter Behring's Straits, is a submarine current, at least

during the summer season. Arriving in the icy sea, still warm and strongly saline, it mingles with the cold and light water which descends into the Atlantic by Baffin's Bay.

The great mass of the Kuro-Sivo traverses the Northern Pacific from east to west with a graceful curve, no less beautiful than that formed by the islands that are washed by its waters; then bends gradually to the south-west and south, to coast the shores of California; finally, in the neighbourhood of the tropics, it changes its direction again, and is lost in the equatorial current, enclosing in its circuit a floating forest of seaweed hardly less extensive than that of the Pacific.

Contrary to Humboldt's Current, which rolls its cold waters and drives before it icebergs to refresh the dry and burning atmosphere of Peru, the Gulf-stream of the Japanese carries along the coasts of Sitka and Vancouver's Island a mass of waters warmed by a long sojourn under tropical heat, and by its vapours brings spring to regions which without it would have a very severe winter. It bears on its waves the fragments which it has received from the coasts of the Moluccas, the Philippines, and Japan. To the inhabitants of the Aleutian Islands and Alaska it gives, as fuel, camphor-wood and other odoriferous trees from southern countries; it serves, too, as a highway for all kinds of waifs, carries away disabled ships; and numberless traditions relate how Japanese sailors were drifted afar and landed against their will on the coasts of America. And it might be to an adventure of this kind that the Chinese navigators owed their discovery of the New World ten centuries before Columbus, if it is true that the land of Fusang, mentioned in the annals of China, is in fact the region of Mexico and Guatemala. But although formerly accepted by Neumann, d'Eichthal, and some other learned scholars, this identification is now almost unanimously rejected by historians and geographers alike.

CHAPTER X.

LATERAL EDDIES.—RENNEL'S CURRENT.—COUNTER-CURRENT IN THE SEA OF THE ANTILLES.—EQUILIBRIUM OF THE WATERS IN THE BALTIC, THE BOSPHORUS, AT THE ENTRANCES TO THE MEDITERRANEAN AND THE RED SEA.—EXCHANGE OF WATER AND SALT BETWEEN THE SEAS.

NONE of those great currents which wind through the oceanic basins show in their exterior contours the same sinuosities as the seas through which they flow. While most of the shores present a succession of promontories and gulfs, the currents stretch in long regular curves, which in their vast sweep indicate but generally the form of the depression which contains them. Every considerable gulf which is separated from the ocean by any projecting land, remains outside the whirlpool of waters, unless it should be in the very axis of the current, like the sea of the Antilles. Yet even in those parts which do not share in the general circulation, the waters do not remain perfectly stationary. They also have their circulatory system, and it is from the great maritime current that each secondary eddy receives its impulsion.

A remarkable example of these currents of the secondary order is presented on the west of Europe in the semicircular basin formed by the coasts of Spain, France, England, and Ireland. A portion of the waters of the Gulf-stream coming from the north and north-west strikes the coasts of Galicia and the Asturias; it turns east towards the extremity of the Gulf of Gascony, flows along the shore of the Landes, then that of Saintonge, Poitou, Bretagne, and returning in a north-west and west direction, forms a sort of liquid barrier across the Channel. To the south of Cape Clear this oceanic river, known under the name of Rennell's Current, after the English savant who discovered its existence, finally enters the Gulf-stream, and returns to the south with the waters of the ocean. Thus a complete circuit is made around the basin, analogous to that which occurs in each of the great oceans of the world. Rennell's Current, in its turn, coasting at a greater or less distance the shores of the continent, sends out into the little bays currents of a third order, which also complete their circular movement, like the Gulf-stream and the Kuro-Sivo; and so by lateral transmission, the circulation of the waters is continued from oceans to gulfs, from gulfs to bays, and from these to the creeks. These secondary currents, however, are usually much less regular than the general currents, and navigators have ascertained that at times Rennell's Current has flowed in a completely reversed way to its normal direction.

Secondary currents generally move in a course exactly opposite to that of the principal stream, of which they are only a branch bent back on itself. Either

permanently or temporarily they are found in all seas, open or inland, in all gulfs and bays of the ocean. Even the sea of the Antilles, the waters of which are carried almost *en masse* towards the Gulf of Mexico, presents at its western extremity a permanent current, which tends from the shores of the isthmus to those of Columbia. A vessel drifted by the principal current into the neighbourhood of Nicaragua, would only have to ascend to Colon, and then abandon itself to the waves in order easily to accomplish its return voyage, borne by the waters which flow incessantly in the direction of Carthagena and Santa Marta. Many lazy seamen never pass from the ports of the isthmus to those of terra firma in any other way. Regardless of time, they let themselves be rocked by the billows without even taking the trouble to hoist the sails. Their bark, slower than a tortoise, advances at the most but a mile an hour, and after eight or ten days spent on the passage, they finally perceive the bluish mountains of New Granada, and its sandy shores shaded by cocoa-nut trees.

There are some currents which are evidently produced by a disturbance of equilibrium between two levels. Thus the Baltic Sea, which receives more water by the contributions of rivers than it loses by evaporation, must necessarily distribute its superfluity in the North Sea through the straits of the Sound and the two Belts. Nevertheless, these outlets being large and deep enough to diffuse the superabundant water in a little time, the current is not permanent. Waves from the North Sea, driven into the Baltic by the westerly winds, frequently meet it, and from this conflict of waters arise local and unexpected movements, dangerous to ships. Every four days the waters on the surface flow on an average for forty-eight hours towards the Cattegat, then flow back into the Baltic for one day, and during another day there is no sensible movement in either direction. Often, too, according to Forchhammer, the two contrary currents glide one above the other; the lighter on the surface, coming from the Baltic, and the other from the North Sea, heavier by reason of the salt it contains, flowing beneath.

At the other extremity of Europe similar phenomena occur in the Bosphorus, at the outlet of the Black Sea. This strait, which receives the superabundant waters of the Euxine, presents a mean breadth of more than a mile, with a depth of 15 fathoms, so that if the waters of the sea flowed there in a continuous manner, as in the bed of a river, and the swiftness of the current were only about $1\frac{1}{4}$ mile per hour, it would not discharge less than nearly 36,000 cubic yards per second. But it is probable that all the united affluents of the Black Sea and the Sea of Azov supply hardly the half of this quantity; and, besides, a great part of the water brought by them is carried off again by evaporation. The Bosphorus is therefore too large to serve as the bed of a single current flowing from the Black Sea into the Sea of Marmora. It has been observed that the waters ordinarily descend towards the Mediterranean, with a speed of from 2 to 4 miles an hour; but the existence of tolerably rapid lateral counter-currents has also been established; and sometimes the winds blowing from the west cause the principal current to flow back through the strait. A submarine movement of the waters in the direction of the Black Sea also exists, as already ascertained by Marsigli in the last century, and again more recently by direct experiments made on board the English vessel *Shearwater*. In depths of 10 or 12 fathoms the stream sets with great velocity from the Dardanelles and Bosphorus in the direction of the Black Sea.

In fact, the quantity of salt contained in the Euxine waters would be inexplicable if no back current existed, replacing with a saline fluid the sweet waters constantly discharged from the Black Sea. But for this restitution of marine

water from the Archipelago, it has been calculated that in less than a thousand years the Euxine basin would be converted into a fresh-water reservoir by the copious supplies discharged into it through the large rivers Dniester, Dnieper, Don, Bûg, Danube, Rion, Chorukh, and all the affluents flowing from Asia Minor. Still more rapidly would the Sea of Azov, a mere "liman," or lagoon of the Don, be changed into a fresh-water lake, but for the Strait of Yeni-Kaleh, through which two opposite currents also flow between the inner and outer basins.

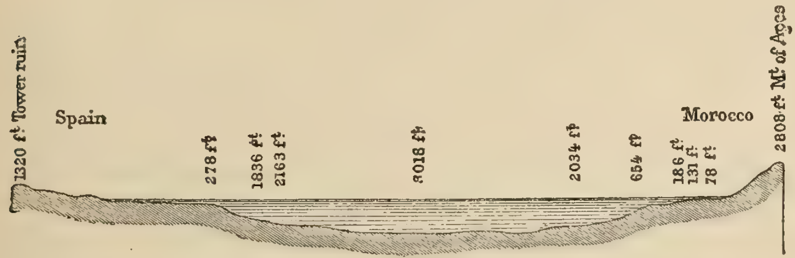
At the western part of the Mediterranean, between Gibraltar and Ceuta, the normal current is that coming from the ocean. In fact, the Mediterranean has not many considerable tributaries. It only receives a single river having a really great mass of water, namely, the Danube; its other affluents of any importance, the

Fig. 25.—The Straits of Gibraltar.

Rhone, the Po, the Dniester, the Dnieper, the Don, and the Nile, bring, on an average, not more than 19,620 cubic yards of water per second. On the other hand, evaporation is very rapid in the basin of the Mediterranean, especially on the coasts of Egypt and Tripoli. We may admit that the quantity of water taken from this basin by the solar rays, and not directly restored by rain, annually represents a section of about 4½ feet; which is probably near enough to the truth, as in the neighbourhood of Genoa, Beaucaire, Arles, and Perpignan, on the northern shores of the sea, the evaporation exceeds four-tenths of an inch per day in the great heat, and nearly 2 feet during the three summer months, while the amount of rain during the year is about 19½ inches. The result is that the Mediterranean constantly loses three times as much water as it receives by its tributaries. It is the ocean then which must fill up the void: a portion of the current which flows

from north to south along the coasts of Portugal and Spain, enters by the Straits of Gibraltar, and spreads far into the Mediterranean in superficial sheets. Nevertheless, if this inland sea did not also send a counter-current to the Atlantic, it would sooner or later be changed into an immense plain of salt. Incessantly losing fresh water by evaporation, and always receiving salt water from the ocean, its liquid mass would become in the end completely saturated, and the crystals of salt would line the marine bed in ever-increasing layers. In order that the equilibrium

Fig. 26 —PROFILE OF THE STRAITS OF GIBRALTAR.



of saltness between the two seas should not be interrupted, it is necessary that the Mediterranean should send its saltest waters to the Atlantic. This is, in fact, what takes place. Besides the lateral eddies that occur along the shores on each side of the current coming from the Atlantic, a Mediterranean counter-current flows below the lighter superficial waters, and takes its direction towards the ocean. This submarine river, which passes the straits of Gibraltar to be lost in the open sea, is, as chemical analyses have shown, a current of heavy water, almost saturated with salt. Thus, an exchange is accomplished through that narrow passage: the Atlantic gives to the Mediterranean the waters which it needs, and receives in return its superfluity of salt to diffuse through the ocean. The sea endeavours incessantly to re-establish its constantly disturbed equality at the boundary of the two marine basins, at a depth of about 546 fathoms.

This harmony of the forces of nature is shown in a still more striking manner at the entrance to the Red Sea. This elongated gulf, which is nearly 1480 miles in length from the Strait of Bab-el-Mandeb to Suez, receives from the atmosphere and the bordering countries so slight a quantity of water that it may be considered as absolutely nothing. It rains but very rarely over the sheet of water lying between the two deserts of Egypt and Arabia, and not a single torrent brings down its waters to it. The Red Sea is therefore only an immense basin of evaporation, and the annual loss is all the greater that the rays of the sun shine almost always from a cloudless sky. The portion of fluid transformed into vapour is estimated at about eight-tenths of an inch per 24 hours; that is to say, nearly 23 feet per year, so that if the gulf was completely closed, the water, whose mean depth does not exceed 220 fathoms, would be entirely dried up in the space of 60 years. Owing to their higher level, the waves of the Indian Ocean are carried into the Arabian Gulf by the Straits of Bab-el-Mandeb; and this flow, superficial or submarine, must make itself felt with all the more force, because during eight months of the year the winds blow from the north to the south, precisely in the axis of the Red Sea, and would thus tend to empty the gulf, if the laws of gravity permitted. But whatever be the swiftness of the current coming from the Indian Ocean, a portion of its water evaporates on the way, and in consequence the liquid mass, diminished by a certain quantity from evaporation, must become

salter and salter in proportion as it advances to the north. In fact, it has been established by direct analyses that the quantity of salt contained in the same volume of water increases gradually from Aden to Suez. From a little more than 39 parts in a thousand at the entrance to the gulf, it rises to 41 and even 43 parts in the thousand at the northern extremity. Dr. Buist, a scholar of Bombay, has calculated that if the Red Sea did not return to the ocean the salt that is concentrated there in consequence of evaporation, it would end in being changed into a solid mass of salt in a space of time certainly less than three thousand years, and perhaps in only fifteen or twenty centuries. Now the Red Sea has already existed for thousands and thousands of years, and its waters (more salt than those of other seas, it is true) are still very far from being in a state of saturation. We therefore come to this inevitable conclusion, that a very salt submarine current flows through the Straits of Bab-el-Mandeb into the Indian Ocean, in an opposite direction, and below the superficial current which supplies the Arabian Gulf. As in houses each door serves at the same time as a passage for two contrary currents, that of the warmer and lighter air which escapes above, and that of the colder and heavier air penetrating below, so in the seas each strait is traversed by two streams, different in temperature and in their saline contents.

All these phenomena of exchange, which occur in such a striking manner at the entrance to the Red Sea, the Mediterranean, and the Baltic, are reproduced in the vast space of the seas wherever the equilibrium of level, warmth, or saltness, is disturbed by any cause whatever. Thus the Atlantic, much better supplied than the South Sea as regards rains and affluents, is nevertheless not more elevated; and on its side the Pacific does not contain a greater quantity of salt than the other oceans. On all parts of the planet, seas bathing the shores of countries most diverse in appearance and geological formation, have a tendency to resemble each other in their composition, saltness, and in most of the other phenomena of their waters. The currents are the great agents in producing this equilibrium in the seas; but by their very mobility, their dependence on the seasons, winds, configuration of the coasts, and finally, by reason of the submarine part of their course, they are exceedingly difficult to observe in a systematic manner,—and among the numerous general and partial currents, there is not a single one, not even the Gulf-stream, whose normal course can be traced with complete precision. Happily, scientific observations are now being multiplied over all the seas; they add to and unite with one another; and, little by little, approach the truth by approximations which result from the comparison of facts. Every new sounding, every new thermometrical reading, is an acquisition to science, and allows us to follow with a clearer eye the complicated circulation of the waters in the immense labyrinth of the ocean.

CHAPTER XI.

OSCILLATIONS OF THE LEVEL OF THE SEAS.—THEORY OF THE TIDES.

ANOTHER movement which keeps the waters of the sea in a constant agitation is that of the tides. While the currents carry the waves from one pole to the other, and stir the very mass of the ocean, the tides incessantly modify the level by the alternations of ebb and flow, which they impart to its waters. They raise or depress without relaxation the mass of waves on all the shores of the globe; the strand, which by turns they invade and lay bare, becomes debatable ground between the two elements, and successively forms a part of the oceanic basin and the continental surface. Twice a day vast plains of sand like those of Mount St. Michael are invaded by the waves, deep bays are formed far into the land, and barks glide with sails spread above the path which the pedestrian has just quitted. Twice a day the same tidal wave causes the waters brought to it from the continents to return back again, transforms simple rivulets into large rivers, changes basins filled with mud into vast inland harbours, and carries fleets of ships over sandbanks and hidden rocks. Six hours afterwards all is changed. The tidal ports are strewn with ships stranded and lying in the mud, the mouths of rivers allow their islands of alluvium to emerge, and great bays are no more than plains of sand. Thus the outline of continents incessantly changes in appearance; the girdle of estuaries and ports, beaches, rocks, and sandbanks which surround their coasts, continually alter, and change the geography of the shores in the same proportion. Besides, movements so considerable cannot occur without being accompanied by very powerful currents, flowing alternately from the open sea towards the coast, and from the coast to the open sea, and contributing greatly to the general circulation and mingling of the waters in the ocean. The influence which the ebb and flow of the tides exercise indirectly on the commerce and civilization of nations is immense; it is to these movements of the sea that England owes in great part her power and glory.

In all times the people dwelling on the borders of the ocean have understood, without being able to account for it, that the alternate phenomena of ebb and flow depend on the position of the moon and sun relatively to the earth. The coincidences that they saw renewed each day between the movements of the tides, and those of the large heavenly bodies, could not leave them in any doubt of this. Sailors and fishermen, accustomed to look to the sky for the signs of the weather, and indications of the route which they ought to follow, had no trouble in ascertaining that the return of every second tide corresponds exactly to the passage of

the moon over the same degree of the heavens; that is to say, to the commencement of a new lunar day. Following the phases of the moon, at new, half-moon, or full, they saw the tides change in a regular manner, and become successively higher and higher, and afterwards, from day to day, lower, till the end of the lunar month. Finally, the movements of the sun also announced to them beforehand the approaching state of the waves, for the equinoxes of March and September are always accompanied by very high tides. These coincidences between the phenomena of the sea and the movements of the moon and sun are so striking, that all barbarous maritime tribes have remarked them, and have rudely symbolized the idea in their songs. Thus the Scandinavian *sagas* represent Thor, the god of winds, blowing the water with a horn which he plunges into the depths of the ocean, and by his powerful breath causing the waves to rise and fall by turns. What can this strange legend signify, if not that the regular oscillations of the tide depend on the cosmical forces to which the planet itself is subject?

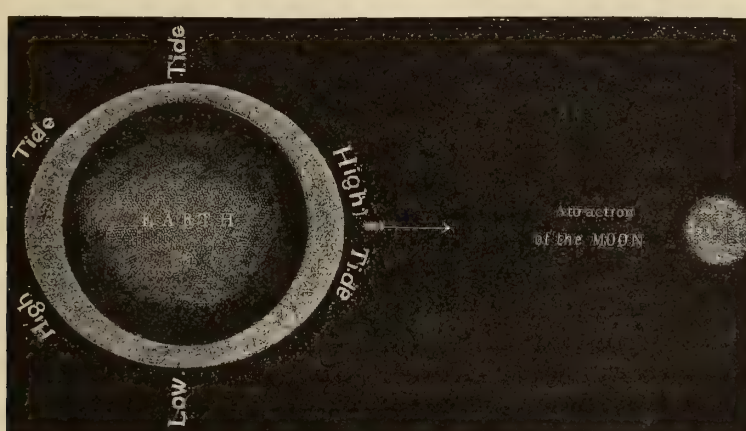
Nevertheless, these symbolic tales of the ancient Scandinavians are far removed from that scientific theory of the tides which the researches and sagacity of Newton and Laplace have established. Even Pliny, when he affirmed clearly that the tides are due "to the combined influences of the sun and moon," restricted himself to summing up in precise terms what all the dwellers on the shores of the ocean knew; but he could not explain in what manner this influence was exercised. The explanation of the mysterious phenomena of the periodical swelling of the waters could only be attempted in modern times, with the aid of the knowledge obtained by astronomers on the motion of the celestial bodies, and with the powerful means of investigation which mathematicians have supplied them with. Kepler first indicated the course to be followed; and Descartes, and then Newton, each gave his theory explaining the tides, the one by pressure, the other by the attraction exercised by the sun and moon on the mobile waters of the sea. It is the latter theory, that of Newton, which was developed later, much modified by Bernouilli, Euler, and Laplace, and which Lubbock, Whewell, Chazallon, and so many other natural philosophers have since compared with observations made on the shores of the ocean. Being very satisfactory in most respects, it is now very generally accepted; but it still has eminent opponents, among whom F. Boucheporn must be named; many of the secondary facts are still to be elucidated, and many local phenomena are not yet understood. To follow the tides in their progress and fluctuations across the seas, it is not sufficient to know the laws of gravitation, and to calculate with the most rigorous exactitude the movement and position of the heavenly bodies; one must also know all the facts relative to the movements of fluids, and know how to apply to all their phenomena of acceleration, retardation, increase, interference, and equilibrium, the most complicated and most minute formulæ of high mathematics. It would also be indispensable to know every fact respecting the form of the shore, and the inequalities of the bed of the sea.

Reduced to its principal elements, the theory of tides set forth by Laplace, and generally adopted since, is very simple. The earth is not an isolated body in space; it is attracted by all the nearer heavenly bodies, and it is indeed in great part this force of gravitation which causes it to turn round the sun, and retain the moon as its satellite. Let us imagine for an instant the earth to be covered with water over all its surface, and subject to the attraction of the moon alone. This superficial part of the planet would be more strongly attracted than the solid portion, since it is nearer to the moon which attracts it; and owing to the facility with which liquid particles glide one over the other, it would swell, so to say, towards the

moon till its weight would be in equilibrium with the attracting force. It would then form an intumescence, the summit of which would be exactly on the ideal line which unites the centre of the earth to that of the moon. On the other side of the planet, according to the general theory, the waters ought to swell in a corresponding wave, and that from a precisely contrary cause. The liquid strata on this part of the earth being farther from the moon than the solid kernel, are less attracted than it, and in consequence must remain slightly behind, thus forming a new intumescence, the summit of which will be found on a prolongation of the line uniting the planet with its satellite. Considered as a whole, the mass of marine waters would thus assume the form of an ellipsoid, having its greater axis directed towards the moon, which is the centre of attraction. It results from this, that the tide ought to be nothing at all, or very slight, at the poles; since in its revolution the moon, while moving to the north and south of the equator, maintains itself at the zenith of tropical or sub-tropical regions.

If the earth remained immovable these two waves would advance slowly, following the course of the moon; but in consequence of the rotation of the earth, they

Fig. 27.—Lunar Tide.



ought to move rapidly in pursuit of one another over its circumference: the wave of the greatest attraction moving incessantly over the part lighted by the rays of the moon, while the wave of the weakest attraction is propagated from the other side of the earth on the part farthest from the satellite. In the space of a lunar day, that is to say, within the 24 hours 50 minutes during which the earth has successively presented all parts of its surface to the planet which accompanies it, the two waves ought each to accomplish a complete circuit around the globe, and each should have a total duration of 12 hours 25 minutes. This is, in fact, what takes place over all seas. As to the numerous variations presented by this phenomenon, in its height and the precise moment of its appearance, they depend on the obstacles of every kind which the rocks, islands, continents, oceanic currents, and winds oppose to the free circulation of the waters.

Nevertheless, the moon is not the only heavenly body whose attraction is manifested in a sensible manner on the waves of the ocean. The sun, which draws the moon in its immense orbit across the heavens, is near enough to our planet to raise the liquid particles of our ocean also. The total attraction exercised by the sun on the earth is even 162 times greater than the total attraction of the moon, and

in consequence it would raise the tides into real mountains as high as the Cevennes (5000 to 6000 feet) if the true cause of the tides was not to be found in the difference of attraction exercised on the waters of the different parts of the earth. The distance from the moon being equal to 60 terrestrial radii only, the action of the satellite is much stronger over the nearer oceanic regions than over the waters situated thousands of miles farther off. The sun, on the contrary, acts nearly in the same manner on the watery particles of the whole surface of all the seas. According to the results obtained by the calculations of mathematicians, the attrac-

Fig. 28.—Syzygy Tide, during New Moon.

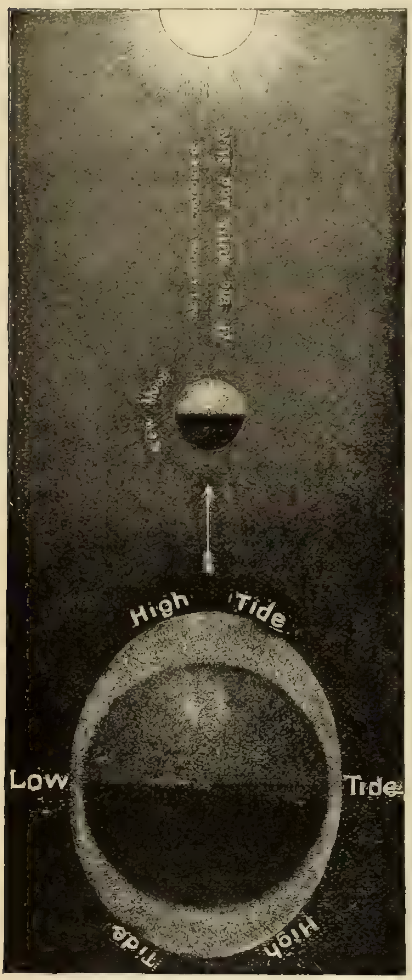


Fig. 29.—Syzygy Tide, during Full Moon.

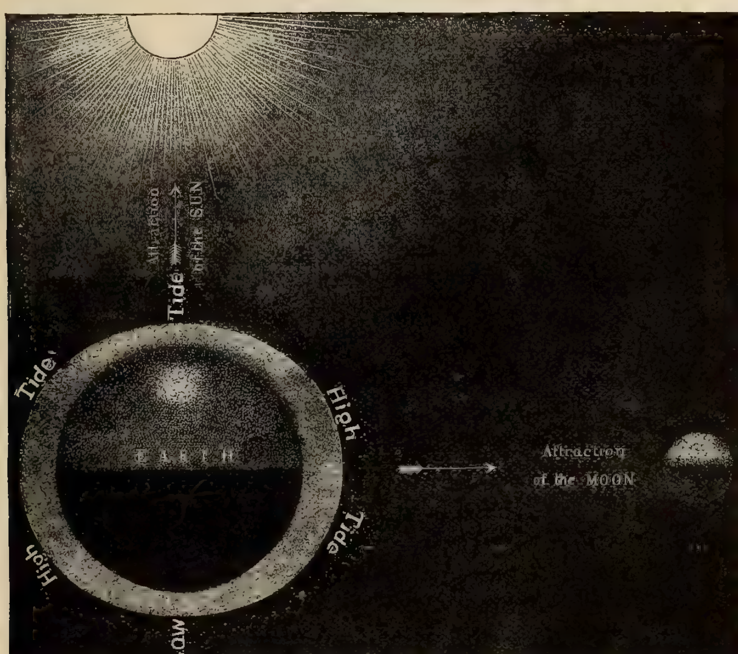
tive force exercised by the sun in elevating the waves is, as compared to that of the moon, in the proportion of about a third.

Two tidal waves, the lunar wave and the solar wave, are thus raised on the surface of the sea. They ought to revolve, the one in the space of 24 hours 50 minutes, and the other in 24 hours. But these two waves, so distinct in their origin, are not separated in their course around the globe; owing to the incessant mobility of the waters they mix and are confused, and it is by calculation alone that we can discriminate in their common mass the part that is to be referred to each of the two

heavenly bodies. These two united intumescences move together around the earth in a direction from east to west; that is to say, in the opposite direction to the rotation of the globe. Serving thus as a drag upon the planet, they must in the long run lead to that slackening of its speed which the calculations and deductions of Meyer, Tyndall, Joule, Adams, and Delaunay lead us to consider as inevitable.

When the moon, called new, turns its dark face towards us, and is thus in nearly the same direction as the sun relatively to the earth, the attractions of the two great celestial bodies join together, and the two tidal waves, raised at the same time towards the same point of space, are exactly superposed. They form those tides of syzygy or high water, called spring-tides, which rise to such great heights along our shores. At the time of full moon, that is to say, when the satellite, entirely lighted, is in direct opposition to the sun, new tides of syzygy not less elevated than the first are formed; for, under the influence of the heavenly bodies situated

Fig. 30.—Tide during Quadrature.



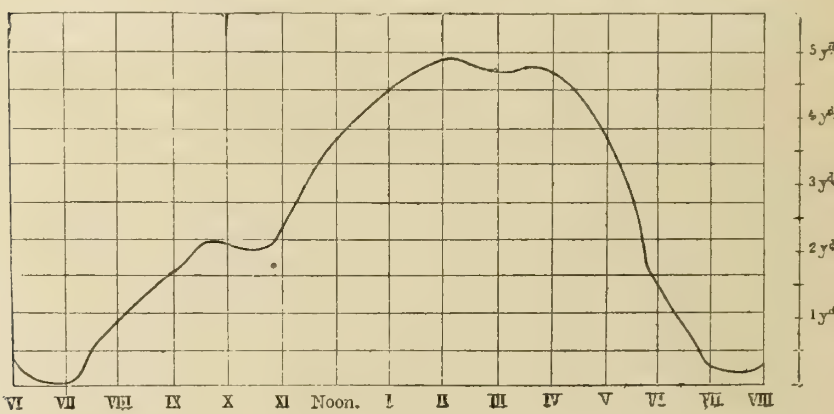
opposite to each other, a double intumescence is simultaneously produced on both sides of the earth. During none of the other phases of the moon does this coincidence exist; at the time of quadrature, the two great movements of the waves oppose one another, and the tidal wave, which represents then the lunar wave diminished by the entire solar wave, is less elevated than during the other phases of the moon. If the two attracting forces were equal in power, the neutralization of the tide would be complete, and the level of the sea would remain undisturbed.

To give an idea of the fluctuations which occur during the course of an entire tide, under the influence of the heavenly bodies, and which are variously modified by the atmospheric currents, the form of the coast, and inequalities of the bed of the sea, we borrow the following figure from Beardmore.

The periods of the tides are exactly those of the bodies which raise them The

semi-diurnal period of 12 hours 25 minutes is comprised between the passage of the moon over the two opposite meridians of the earth. The diurnal period, during which the ocean swells and subsides twice, corresponds exactly to the duration of one apparent rotation of the satellite around our planet. There is the same coincidence for the semi-monthly period; the return of the spring-tides occurs from fortnight to fortnight with the return of the full or new moon, and the monthly period is completed when the series of lunar phases recommences. Nor is this all; the tides have also their semi-annual period, from the equinox of March to that of September, for the sun being then directly above the terrestrial equator, exercises a stronger attraction on the liquid masses, and the waves of the spring-tides rise to a greater height than usual. Finally, an annual period is marked for the tides by the epoch when the earth is nearest the sun. This epoch falls during the winter of

Fig. 31.—Tide at Southampton, 2nd August, 1859.



the northern hemisphere, and it is then indeed that the spring-tides rise with most force on the coasts of our continents.

Thus the phenomena of the tides are intimately connected with the celestial movements, and every change in the relative position of the bodies which attract our planet manifests itself by a corresponding change in the level of the seas. Knowing beforehand the route which the earth follows in space, astronomers foresee thereby even the future oscillations of the wave, and can trace their curve for centuries to come. Nevertheless, it must be admitted, this curve is only true in theory; for if the tides in their origin be due to astronomical causes, they are also subject to variations from terrestrial phenomena. Like the winds, currents, and all the other manifestations of planetary life, they present incessant variations, and are, so to say, in a continual genesis.

CHAPTER XII.

THEORY OF WHEWELL ON THE ORIGIN AND PROPAGATION OF TIDAL WAVES. —ORIGIN OF THE TIDE IN EACH OCEANIC BASIN.—"ESTABLISHMENT" OF PORTS.—"COTIDAL" LINES.

THE English natural philosopher, Whewell, who during long years made laborious researches on the phenomena of ebb and flow, was the first to apply the name of "cradle of the tides" to the great continuous sheet of water which covers almost all the surface of the southern hemisphere. It is in this vast basin, of which all the other oceans are mere ramifications, that the combined attraction of the sun and moon would first raise that wave, which from shore to shore dashes at length against the coasts of Greenland and Scandinavia. It is there that the water, a few instants after the passage of the moon over the meridian, would itself attain the level of its highest elevation, and would form that first regulating intumescence, which the surface of all the seas would obey one after the other, as a cord shaken at one of its extremities oscillates to the other end in rhythmical vibrations.

According to this theory, the tidal wave circulates incessantly throughout the Antarctic Ocean, to the south of the extremities of the three continents of Australia, Africa, and South America. It follows from east to west the apparent course of the moon, and thus describes a real orbit round the earth similar to that of the celestial bodies. Even in the central Pacific and the Indian Ocean, the tide obeys this normal impulse towards the west. It strikes the coasts of Australia and New Guinea almost simultaneously; then thirteen or fourteen hours afterwards it dashes on the eastern coast of Africa, from the bank of Lagullas to Cape Guardafui; finally seven or eight hours later the coast of South America is struck in its turn from Tierra del Fuego to the estuary of La Plata.

To the north of those large oceanic tracts of the South Sea, the tides, not having the same facilities for developing themselves in a normal manner, would be obliged to change their direction. But in spite of this deviation, they would not the less be, Whewell thinks, continuations of the primitive swelling. Arrested by the American continent, which bars its passage, the tidal wave would rebound towards the north, and follow the contours of the oceanic valley, like a torrent enclosed in a mountain gorge. Striking the coasts of America and those of the Old World under the same latitude at the same time, and at an equally oblique angle, it reaches almost simultaneously, on either side of the Atlantic, the Bay of Fundy and the Irish Channel, where its highest known elevation is observed. The tidal wave accomplishes this passage of about 6000 miles, from the Cape of Good Hope to the British Isles, in about fifteen hours. But its entire voyage, from the centre

of the Antarctic Ocean, must have lasted more than a day, and in consequence of the gradual slackening of speed of the waters on the shores of Great Britain, it is only after two days and a half that the tidal wave reaches the mouth of the Thames. Thus the moon would have had time to raise five successive tides in the Pacific Ocean before the motion of the liquid mass would have been propagated to the entrance to the North Sea.

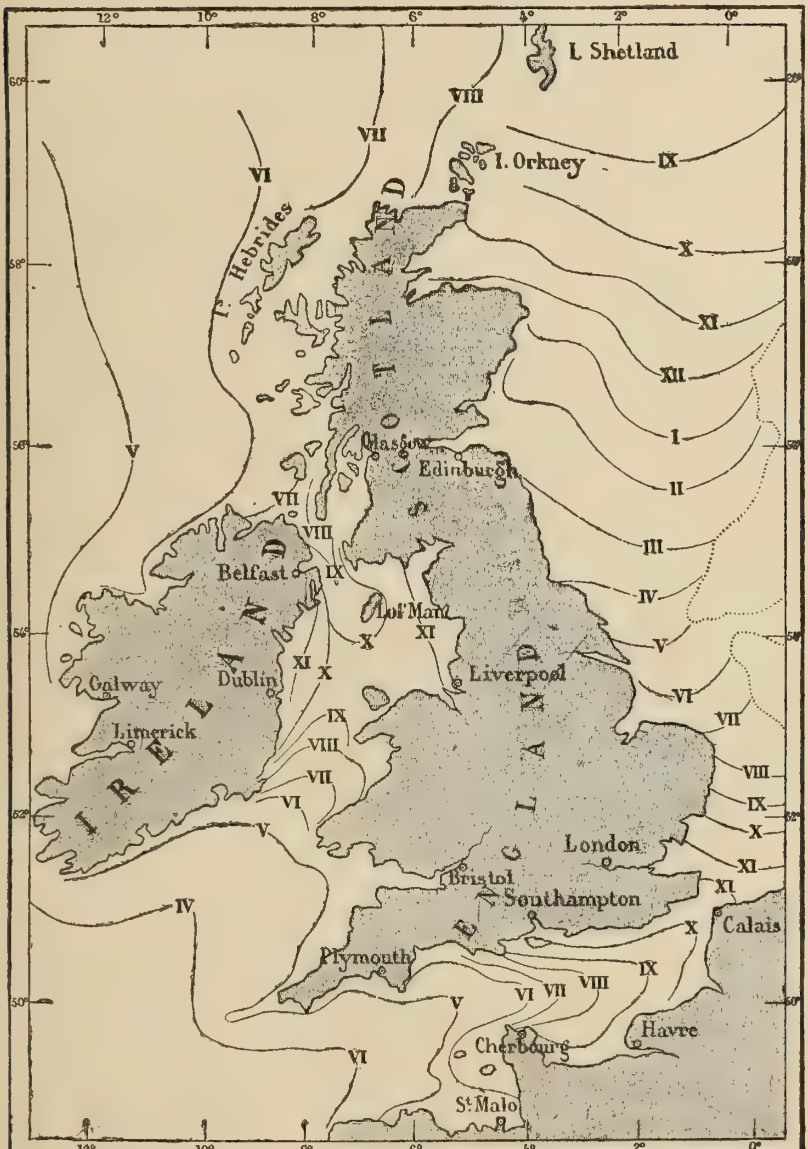
Such is the theory which the labours of Whewell have caused to be long considered the very expression of truth. Nevertheless, it is not certain that things occur in this way. In fact it is ascertained that in each oceanic basin the tide seems to start from the centre, and to be propagated in all directions parallel to the general direction of the coasts. We may naturally conclude from this, that each great division of the ocean, considered as an isolated sea, is really the cradle of the tides which break upon the surrounding shores. What confirms this idea, too, which appears so probable at first, is that the various oceans are separated from one another by spaces where the regular tide is hardly perceptible. Thus between the South and North Atlantic, whose precise boundary may be defined by the promontory of St. Roque and Cape Verde, there exists a wide zone where the tide hardly changes the maritime level more than about 23 to 27 inches, as at the islands of Ascension and St. Helena. Besides, according to the theory of Whewell, the tidal wave on the coasts of the Argentine Republic and Brazil, ought to propagate itself from south to north; whilst, on the contrary, the movement proceeds from north to south, from Pernambuco to the mouth of the La Plata. When we see a tidal wave rise off the bank of Newfoundland, in the deepest part of the Northern Atlantic, it is not therefore necessary to consider this as the same wave which twelve hours before was raised near the bank of Lagullas at the entrance to the South Atlantic. It is perhaps better to regard the oscillations which occur at the same time in both hemispheres as coincident but independent phenomena. And how are we to explain the fact that the tidal wave, which in the southern waters has a mean height of scarcely more than 40 inches, acquires such large proportions when it reaches the Atlantic seaboard. After a journey of three days across a basin of this depth, we should expect the very opposite result. Thus in 1868 the earthquake waves, from 40 to 44 feet high at their starting-point on the coast of Peru, had fallen to 10 feet in New Zealand, and to less than 20 inches on the Australian shores.

Nevertheless, in each isolated basin the movements of the sea are mainly as Whewell has described them. On the coasts of France and the British Isles the tide certainly comes from the open sea, and in its progress along the shores, the original motion which the attraction of the sun and moon produced in the middle of the open sea continually decreases. On penetrating into the shallower seas which surround Ireland and Great Britain, the tidal wave gradually slackens. After having struck Cape Clear and the promontory of Land's End, it is propagated with such slowness around the two islands, that 19 hours elapse before it arrives at the Straits of Dover, where it meets with another wave, newer by 12 hours, which has come by the shorter route of the Channel. Whence comes this slackening of the wave? The researches of astronomers and natural philosophers inform us, that the speed of the tidal wave is proportioned to the depths of the ocean; driven by an equal force, the circumference of a wheel turns the faster the greater its diameter; in the same way the tide hastens or slackens its movement, according to the depth of the watery mass which it traverses. In those latitudes where the bed of the ocean is 5000 fathoms from the surface, the speed of the wave is about 528 miles an hour; where the depth is only about 50 fathoms, the tide is not propa-

gated more than about 60 miles in the same space of time; finally, when the bottom is at about 5 fathoms below the marine surface, the movement of the waters is greatly retarded, and does not exceed 15 miles per hour, that is to say, 440 yards per minute.

In consequence of the delay which the tidal wave experiences, the "establish-

Fig. 32.—Cotidal Lines of the British Isles.



ment," that is to say, the time which elapses between the passage of the moon over the meridian and the moment of full tide, varies singularly in different ports situated near each other. Thus while at Gibraltar there is usually a coincidence between the astronomical and marine phenomena, and the establishment is reduced

in consequence to zero, this interval is about an hour and 15 minutes in the port of Cadiz, and 4 hours at Lisbon. At Bayonne, as at Lorient, it is 3 hours 30 minutes; at the mouth of the Gironde and at Cherbourg it is 7 hours 40 minutes; at Havre 9 hours 15 minutes, at Dieppe 10 hours 40 minutes, at Dunkirk 11 hours 45 minutes. The establishment varies on every shore according to the speed of propagation of the tide across the open seas and in the gulfs and estuaries.

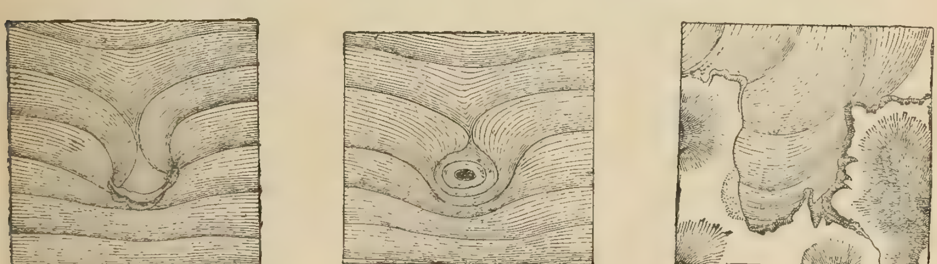
The sinuous line which unites all the points in the ocean where the full tide occurs exactly at the same hour, has received from Whewell the name of *cotidal* line; it indicates the curve which the crest of the tidal wave forms at any one moment on the surface of the sea. It is around the British Isles that these lines of simultaneous swelling, or of equal establishment, have been most carefully traced. By calculation and direct observation, that part of the oscillation on the mobile and almost always agitated surface of the sea, which is to be referred to the phenomena of ebb and flow, has been detected; and much more exact maps of these swellings and depressions, which are invisible on the open sea, have been drawn, than of the vast continental regions which are at present but little known. Thanks to the labours of Whewell, Airy, Lubbock, and Beechey, one can now follow the whole series of cotidal lines which succeed one another from hour to hour around these two great islands, from the crest coming in from the open sea, at the entrance of the English Channel and the Irish Sea, 4 hours after the passage of the moon over the meridian, to the swelling which 19 hours later reaches to the south of the German Ocean and penetrates into the funnel of the Straits of Dover, where it meets the other tidal wave coming directly by the Channel. The general form of these curves demonstrates in a striking manner that the speed of propagation of the tide is in proportion to the depth of the seas. Everywhere we see the cotidal lines develop their convex part above the deeper valleys of the marine bed; everywhere we see the wave slacken its speed in the neighbourhood of shallow rocks and shores. One could even by an inspection of these lines of equal intumescence indicate exactly those parts where the lead would descend lowest; so intimate is the connection of cause and effect between the depth of the sea and the progress of the tide.

CHAPTER XIII.

APPARENT IRREGULARITIES OF THE TIDES.—EXTRAORDINARY SIZE OF THE TIDAL WAVE IN CERTAIN BAYS.—INTERFERENCE OF EBB AND FLOW.—DIURNAL TIDES.—INEQUALITIES OF SUCCESSIVE TIDES.

INNUMERABLE are the apparent irregularities which occur in the phenomena of the tides, in consequence of the inequalities of the submarine surface, the thousand indentations of the shore, and the alternations of winds and currents. Though the cause of the movement be the same everywhere, we can still say that at no point of the sea do the ebb and flow present a perfect agreement in their progress. Each promontory, each islet, each rock is bathed by waters having a distinct rule in the propagation of their tides; every obstacle which breaks the regular course of the oscillations modifies the whole of the graceful curves which bend around it. The above figures, borrowed from Lubbock, give an idea of these variations in the march of the waves.

Figs. 33—35.—Irregularities in the Curves of the Tidal Waves resulting from the form of the sea-bed, projecting rocks, &c. (after Lubbock).



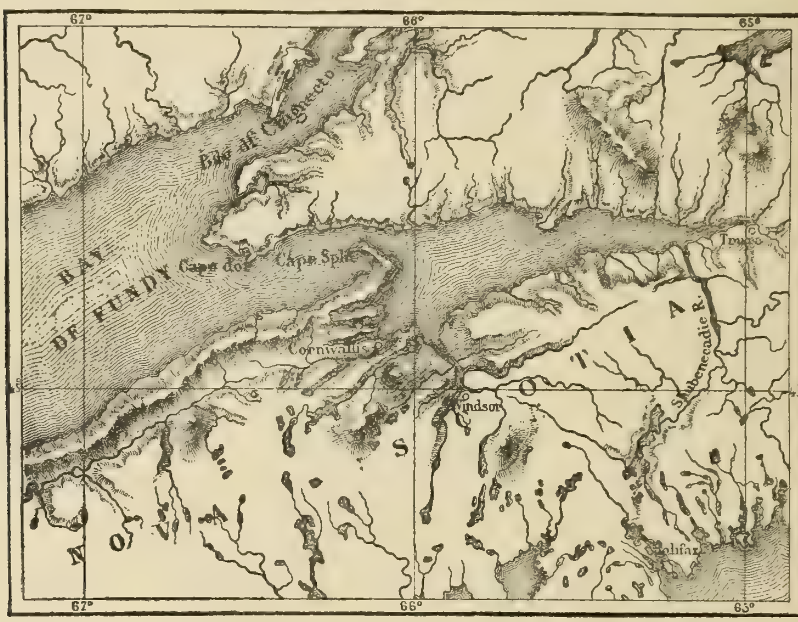
The difference which most strikes the minds of navigators and inhabitants of the coast is that of the height of the tides. In one part of the coast the tide hardly makes itself felt, even during the equinoctial syzygies; while elsewhere every tide is a real deluge, spreading as far as the eye can see over vast tracts, which emerge again at the time of ebb. This astonishing contrast in the amplitude of the tides results from differences of speed in the progress of the oscillations in the seas and bays of the coast-line. In fact, the great swelling caused by the heavenly bodies may be considered as formed of a great number of successive waves occupying a considerable breadth on the surface of the sea. In the open ocean, all these waves move with great speed; but in proportion as they approach the shores, they slacken their movement, and consequently must gain in height what they lose in rapidity.

From the mere sight of a tidal chart we can affirm that the tide will rise several feet high in all the gulfs where we sea the cotidal lines crowded together, in consequence of the gradual retardation of the wave of intumescence.

In this respect, facts fully confirm theory. The Gulfs of Bengal and Oman, the China Sea, the indentations of the eastern coast of Patagonia, the Bay of Panama, that of Fundy, between New Brunswick and Nova Scotia, the Channel and the Irish Sea, are parts where the waves of equal intumescence follow each other very closely, and it is there too that a greater extent of coast is alternately covered and revealed by the tide. In the port of Panama the tides rise nearly 23 feet, concealing and discovering by turns an immense strand in their diurnal movements, while at hardly 37 miles distant, on the other coast of the isthmus, the ebb and flow are scarcely perceptible.

In the Persian Gulf and the China Sea the amplitude of the equinoctial tide is nearly 36 feet at the extremity of the gulfs. In the mouth of the Severn and

Fig. 36.—Bay of Fundy.



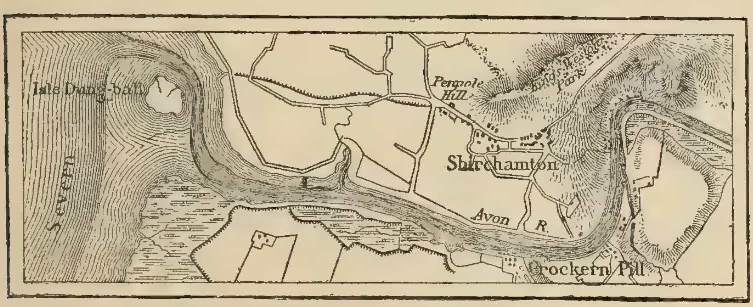
the French bay of Mount St. Michael the difference of height between the spring-tides and low-water is from 45 to 48 feet. To the south of the American continent, in the Gulfs of San-Jorge and Santa Cruz, at the entrance of the Straits of Magellan, Fitzroy has measured tides of from 48 to nearly 66 feet high; finally, in the Bay of Fundy, so well calculated, by the contour of its coast and the surface of its bed, to retard progressively the march of the tide, the difference between high and low water, which is about 9 feet at the entrance, gradually increases to nearly 69 feet towards the extremity of the channel. This is probably the part of the coast where the regular oscillations of the waters are accomplished in the grandest manner. Twice a day immense neutral shores, which are neither land nor sea, change into deep gulfs, and stranded ships rise and float with sails spread, whilst towns lost in the interior of the land find themselves seated on peninsulas invested by the sea. At St. John's, New Brunswick, a cascade is seen to glisten at

the bottom of the port at low water; but when the tide reaches the foot of the cliff, the height of the fall gradually diminishes, and it is at last entirely drowned in the salt waters, which, spreading far over the upper terrace, permit vessels to penetrate into the natural basin formed above the cascade.

Similar phenomena occur in the two bays of Mount St. Michael and the Severn, where rivers and rivulets are also periodically changed into gulfs; where the harbours are tidal ports, in which ships, with the exception of those which are enclosed within the basins, lie on their sides in sand or mud at the time of low water. In the same way the space extending between Noirmoutiers and the coast of La Vendée is alternately an isthmus and a strait; a high road traversed by vehicles winds through the sandy plain between pools of water, and a few hours afterwards vessels with sails spread pass over the same route. Sailors are often seen walking quietly on the shore at a slight distance from their stranded vessel, or else digging in the ground in search of shells; but let the distant rolling of the tide be heard, and in the space of a few seconds the crew is on board, preparations are made for again setting sail, and the vessel, raised by the tide, sails rapidly over the sea.

It is in the bay of St. Michael, on the western coast of Europe, that the rising

Fig. 37.—Mouth of the Avon (after Beardmore).

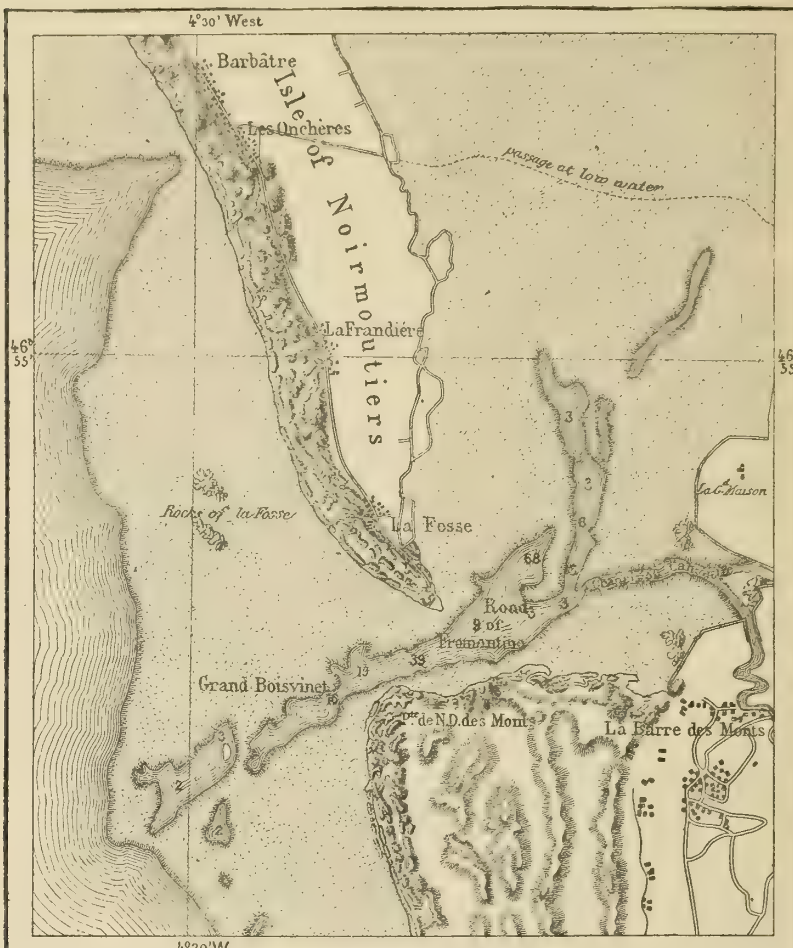


tide presents the grandest spectacle, for in the centre of the bay rises a black granitic rock, "abbey, cloister, fortress, and prison" at the same time, which by its abrupt precipices and its "titanic pile, rock upon rock, century after century, but always dungeon over dungeon," contrasts with the dreary extent of the shore. At low water, the immense sandy plain, above 150 square miles in extent, resembles a bed of ashes. But when the tide, swifter than a horse at full gallop, rises foaming over the scarcely perceptible slope, a few hours are sufficient to transform the whole bay into a sheet of greyish water, penetrating far up the mouths of the rivers as far as the quays of Avranches and Pontorson. At the ebb, the waters retire with the same speed to nearly $6\frac{1}{4}$ miles from the shore, and lay bare the great desert strand, which is intersected by the subterranean deltas of tributary rivulets, forming here and there treacherous abysses of soft mud, into which travellers are in danger of sinking. At the time of spring-tides the liquid mass which penetrates into the bay is estimated at more than 1470 millions of cubic yards, and even at neap-tides the deluge, which pours over the beach twice in the four-and-twenty hours, is not less than about 765 millions of cubic yards. Is it astonishing that such torrents should have been able in former times, when driven by tempests, to break through the chain of sand-hills which protected the rocks of Tombelène and St. Michael on

the north, and to transform into sterile wastes the beautiful country and vast forests which extended to the foot of the peninsula of Cotentin?

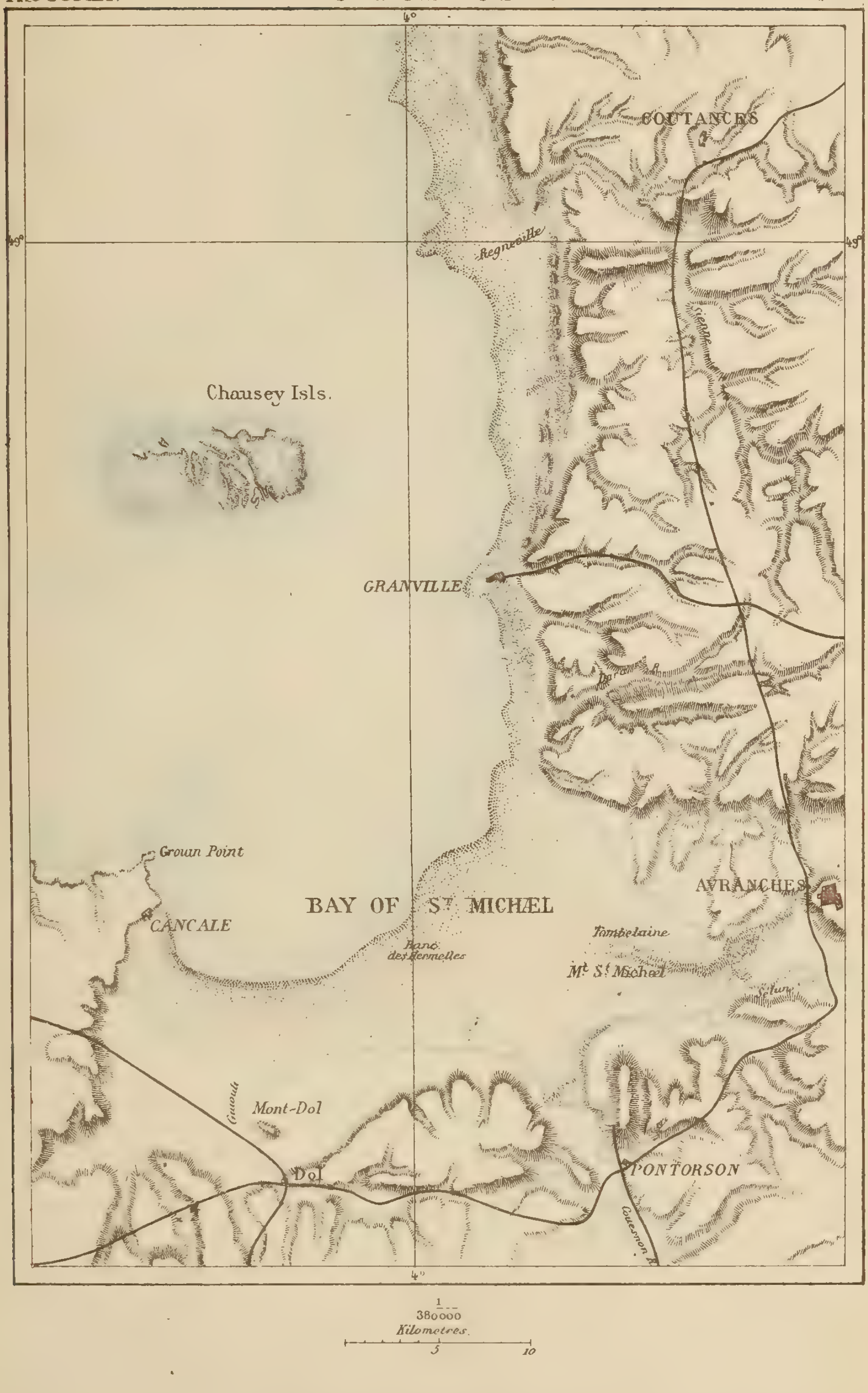
Beechey's observations of the tides of the Channel and the Irish Sea cause it to be regarded as certain that the enormous amplitude of the ebb and flow at the mouth of the Severn, and in the bays of Cancale and St. Malo, arise not only from the gradual elevation of the bottom, but also from the superposition of two waves, which encounter each other. In fact, the crest of the tide which penetrates into

Fig. 38.—Straits of Noirmoutiers.



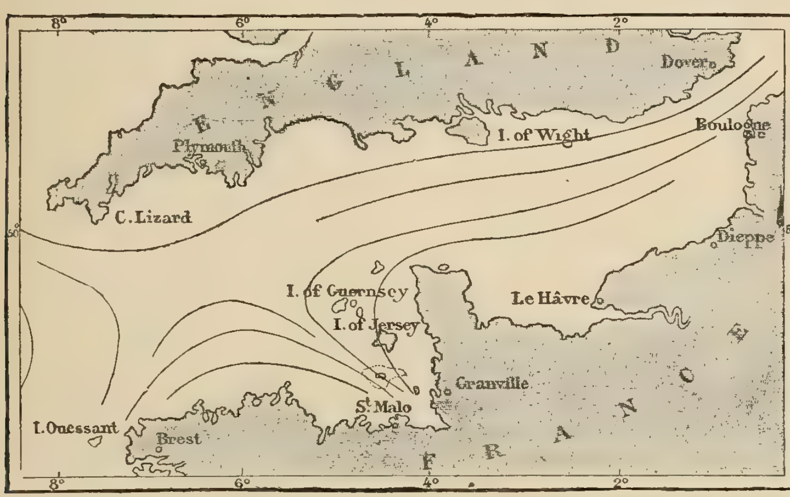
Depth indicated in feet

the Irish Channel meets at the end of the gulf, where the Severn discharges itself, another wave older by twelve hours, which has just made the entire circuit of Ireland. These two waves, united into one, take the common direction which results from their original impulsion, and flow together into the Gulf of the Severn. In the same manner, the tide which enters the Channel meets off Jersey with another wave, which has made the tour of the British Isles in twenty-four hours, and the two joining each other, dash their enormous liquid mass against the strand and rocks of Brittany.


4°
49°
COUTANCES
Regneville
Sienne
Chausey Isls.
GRANVILLE
Groun Point
CANCALE
BAY OF ST MICHÆL
Banc des Hermelles
Tombelaine
Mt St Michael
AVRANCHES
Selune
Mont-Dol
Dol
PONTORSON
Couesnon R.
1/380000
Kilometres
5
10

If two tides coming from opposite points, and meeting at the time of high water, are thus combined in one, they, on the contrary, neutralize and suppress each other, when the ebb of the one crosses the flow of the other. A phenomenon of interference then occurs comparable to that of two luminous vibrations extinguishing each other. Fitzroy was the first who pointed out a region of the ocean where contrary tides maintain the surface of the water in equilibrium. This region is the estuary of La Plata. At sight of this gulf, which is no less than 150 miles at the entrance, one would be tempted to believe that the amplitude of the ebb and flow would be as enormous there as in the Bay of Fundy or the Gulf of St. Malo. But, on the contrary, the tides there are scarcely perceptible. The strong oscillations of the level that have been observed in that estuary are due almost wholly to the regular breezes and the tempests, which depress the waves on one side and raise them on the other. Then, too, as the land-winds generally predominate during the morning, and are replaced in the evening by the sea-breezes, the ebb and flow, obedient to the alternating impulses of the atmosphere, succeed each other every

Fig. 39.—Tides of the English Channel.

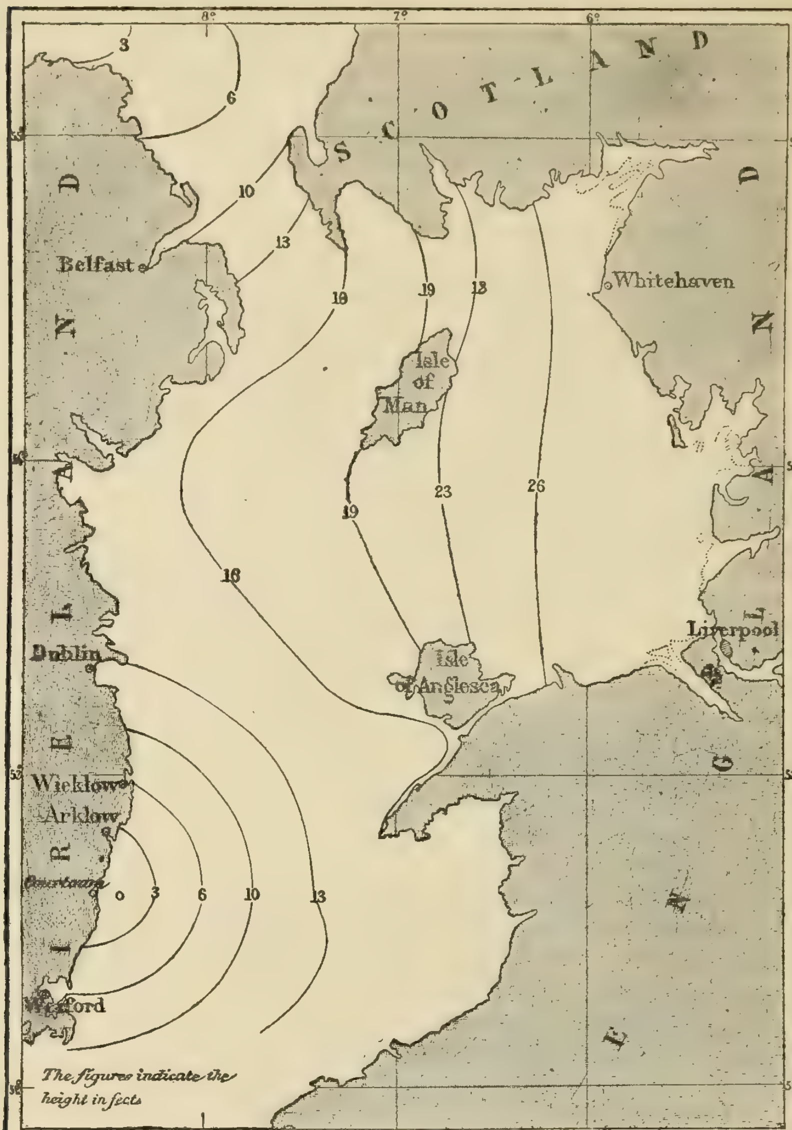


twelve hours; the tide rises in the afternoon and falls the next morning. This apparent anomaly is easily explained by the meeting of high and low water at the entrance of the estuary. The tidal waves which flow to the south on the Brazilian side, and to the north on the side of Patagonia, do not strike the coasts at the same instant daily. They follow each other at an interval of several hours, and the lateral currents which diverge from them succeed one another at the mouth of the estuary of La Plata, so as to maintain the liquid mass at nearly the same level. At the moment when the ebb of the northern tide is about to occur, the southern flow takes place, the pressure of which, exercised in the contrary direction, prevents the waters from falling; then when a new tide from the coasts of Brazil presents itself, the surface of the sea is already lowered in the southern latitudes. The swellings would intersect each other, and on the line of interference the water would be subject to no oscillations.

It is probable that to causes of a similar kind we must attribute the formation of those diurnal, and always very slight, tides which occur at the mouth of the

Mississippi, on the coasts of New Ireland, at Port Dalrymple in Tasmania, to the south of Australia, near King George's Gulf, in the Gulf of Tonquin, in the Bay of Bahr-el-Benat, in the Persian Gulf, in the White Sea, and in many other parts of the ocean. These slow changes of level, the ebb and flow of which each lasts twelve hours, present, like ordinary tides, the greatest diversity in their phenomena,

Fig. 40.—Height of the Tides in St. George's Channel.

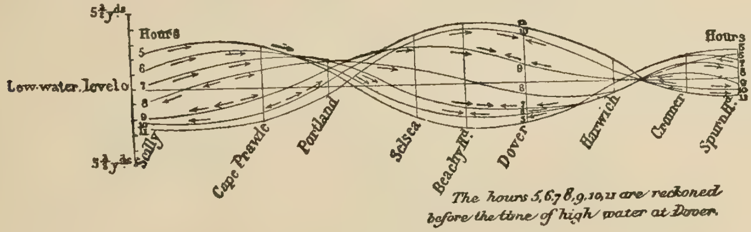


according to the direction of the winds and the currents, the respective positions of the sun and moon, and the parts of the sea where this equilibrium of the waters is established. On the moving surface of the ocean, all the undulations, whatever may be their cause, are mixed and confounded, and in this ceaseless changing and mingling of the waves it is impossible to discern, without long and patient research,

the part taken by each agent in disturbing the perfect repose of the sea-level. The problem can be solved in a general manner only, without taking account of details that have been as yet imperfectly observed. Thus, it is known that in the port of Vera Cruz, and on the neighbouring coast, the winds have a marked preponderance, for they sometimes maintain the surface of the sea at the same level during whole days. At the mouths of the Mississippi, where the daily tide has a rise of little more than 14 inches, it is not less regular in its progress, and its total height each day represents exactly the difference of level between the two composing waves which have crossed each other. Finally, the tide at Tahiti, nearly 12 inches high, is the result of many more oscillations; for four tides, coming from the four cardinal points, meet each other there, all differing in their speed and their hour of high water. It is not surprising that in the middle of this general intersection of the tides of the Pacific Ocean, that of Tahiti is almost completely neutralized.

The Irish Channel, so well studied by Beechey, presents a very curious example of a perfect equilibrium of waters, and that almost opposite the Bristol Channel, where the sea rises and falls alternately above 48 feet. That part of the Channel whose surface remains at rest borders on the Irish coast not far from the little town of Courtown, to the south of Arklow. There, neither rise nor fall in the waters has ever been observed, though the currents of the ebb and flow run along the

Fig. 41.—Crossing of the swellings of the Tides in the English Channel and the North Sea, from the Scilly Isles to the Mouth of the Humber.



coast alternately, with a speed of nearly $4\frac{1}{2}$ miles per hour. The point where the waters are always in equilibrium may be considered as a kind of "hinge" on which the tides turn. Their amplitude is greater and greater in proportion as they are distant from this tranquil region, to the north-east towards Holyhead and Liverpool, to the south-east towards Milford Haven and Bristol. In the North Sea, the meeting of high and low water, not far from the Straits of Dover, is marked by another centre of equilibrium, which seems to oscillate between the coasts of Holland and those of England, according to the atmospheric and marine currents, and the movements of the heavenly bodies. In this place, Hewitt has ascertained that the tide rises two feet only; and it is in this region, where the waters keep almost always at the same level, that the largest and most numerous sandbanks are deposited.

It appears that the two tidal currents which meet near the Straits of Dover, the one coming directly from the Atlantic, the other from the North Sea, do not follow the centre of the Channel, and consequently do not encounter each other directly. The rotation of the earth, which in the northern hemisphere displaces all moving bodies towards the right, causes each of the tidal waves to diverge in this direction. In the Channel the tidal wave, which is directly propagated, constantly leans towards the right, that is to say, towards the south; its force is therefore much greater on the coasts of France than on those of England, and when it has

passed the Straits, it keeps its preponderance on the coasts of the continent as far as the mouths of the Meuse; the tide coming from the north, on the other hand, deviates likewise to the right and flows along the coasts of England. The crossing of these two contrary currents gives rise to numerous gyratory movements off the coasts of France and Great Britain, the incessantly changing curves of which form a veritable labyrinth.

In the roadstead of Havre the meeting of the tides results in a remarkable phenomenon, which is at the same time one of the most useful for navigation. Instead of falling immediately after having attained its point of highest tide, the sea remains steady for three hours, and thus permits vessels to sail all over the road, and to penetrate with ease into the port, floating constantly over deep water. The seamen saw in this fact a sort of miracle, before its true cause had been revealed. When the tide from the Atlantic rolls towards the east to the middle of the Channel, it is arrested in its course by the peninsula of Cotentin, and can only advance freely to the north of the Gulf, towards the mouth of the Seine. The marine level is thus more elevated at the centre than on its shores, and its waters are spread laterally towards the road of Havre and other parts of the coast. At the time of low water, when the ebb prevails in the centre of the Channel, the inclination is changed; but before the waters of Havre can descend towards the central course of the Channel, which carries such an enormous mass of fluid to the ocean, they are kept back by the wave which, after having struck the Cape of Antifer, flows along the shores from north-east to south-west to the Cape of La Hève. Then, when the force of this partial tide fails, another river tide, which has followed the coast of Normandy from St. Vaast to Trouville, still maintains the level, for a time.

In almost all river ports, as we can easily understand, the ebb lasts longer than the flow, for the fluvial current neutralizes the tide during a shorter or longer period, and then adding to the ebb cannot but augment its duration. A fact more difficult to explain is that, whilst in the greater number of ports remote from any river's mouth, the rising tide is shorter than the falling, numerous instances of the opposite are to be seen; and especially in the port of Holyhead. According to the hypothesis generally adopted, this longer duration of ebb ought to be attributed to the rotation of the earth in the direction of west to east. The tidal wave being propagated in the contrary direction, that is to say, from east to west, would meet a certain resistance in the waters which are spread before it. It would rise up and become steeper and more rapid towards the west; while its other slope, that of the ebb, would lengthen itself towards the east. This will explain why the phase of the flow does not last so long as that of the ebb.

The inequalities which are observed in certain parts between two successive tides, are likewise strange and, in some respects, unexplained phenomena. These various inequalities, now in the duration and now in the respective heights of the two tides of morning and evening, or which even affect every oscillation in its entire course, arise in part from the declination of the moon, that is to say, from its varying distance to the south or north of the equinoctial line. But in many cases the differences between two successive tides are relatively enormous, and this explanation is not sufficient. Thus at Port Essington, on the northern coast of Australia, differences in height of nearly 4 feet between the oscillation of evening and morning have been observed. At Singapore, where the mean tide during the time of highest water is nearly 7 feet, the difference between two succeeding tides is sometimes nearly 5 feet. At Kurrachi the daily variation is no less, and in the Gulf of Cambay it attains to nearly 7 feet. At Bassadore, at the entrance of the Persian

Gulf, the duration of one oscillation of the sea sometimes exceeds by two hours that which follows it; and, finally, it has happened at Petropaulovski, in the northern Pacific, that expected tides have never appeared at all. We can explain these singular anomalies only by the intersection of several reflex waves, diurnal and semi-diurnal, which interfere with one another, and the confused oscillations of which are produced by the meeting of moving liquid masses of diverse origin. It is thus that on the surface of a pond, the waves that have risen at different points form an immense network of intersecting lines, which the breeze mingles in undecided wavelets.

CHAPTER XIV.

TIDAL CURRENTS.—RACES AND WHIRLPOOLS.—TIDAL EDDIES.—RIVER TIDES.

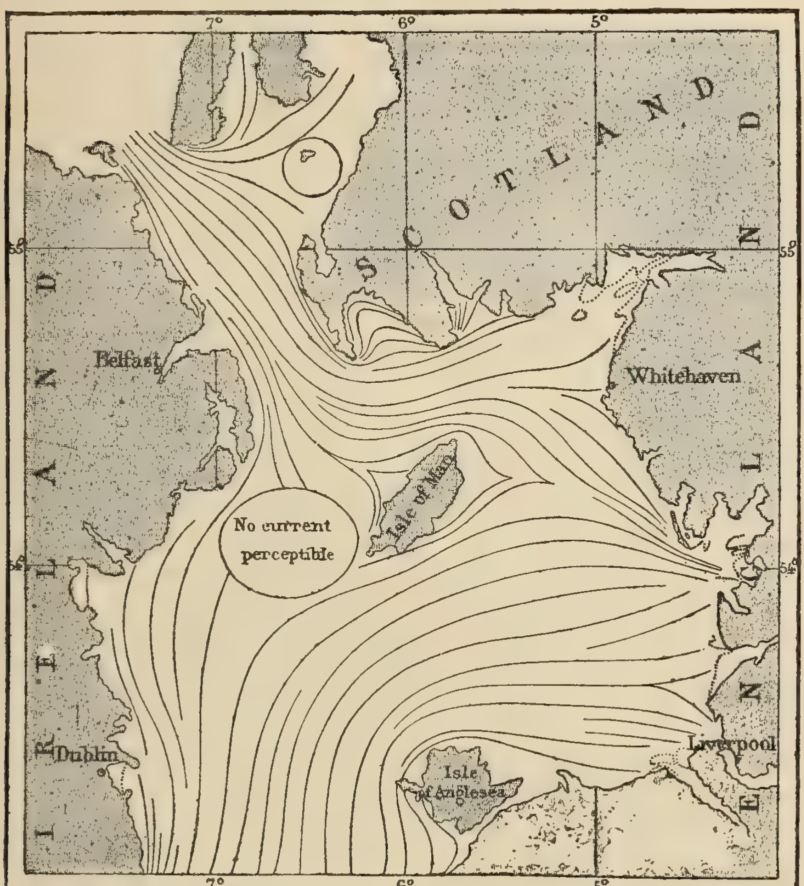
THE popular belief is that the oscillations of the tides are always accompanied by currents changing regularly with the ebb and flow, and tending alternately in one direction or the other. This is, it is true, a pretty frequent phenomenon, especially at the mouths of rivers. Usually when the water rises, a tidal current rushes at the same time towards the shore and into the estuaries of rivers; then when the level of the liquid mass falls, a return or low-water current, swelled by the fresh water from inland, flows again towards the open sea. Nevertheless, this coincidence of the horizontal currents with the vertical oscillations of the ocean is far from being reproduced with regularity in all parts. The tide, being merely a swelling of the sea, can rise without the least movement occurring in one direction or the other. A remarkable example of this is seen in the Irish Sea, so rich in maritime phenomena. In the middle of the channel which separates the Isle of Man from Ireland, the sheet of water keeps perfectly tranquil between the contrary currents, though the water at this place rises more than 18 feet during the spring tides. On the other hand, as one can see at Courtown, on the coast of Arklow, the current determined by the meeting of opposing tides can have a great speed where the surface of the sea neither rises nor falls. Finally, the same wave can follow a constant direction across two contiguous regions of the sea, one of which is at ebb and the other at flow.

The currents which occur in straits in consequence of differences of level, are sometimes extremely violent; and by their abrupt changes, their eddies and whirlpools may be classed among the most dangerous phenomena of the ocean. Thus the entrance to the Gulf of Normandy and the Channel Islands is rightly dreaded by navigators because of the terrible speed which the tidal currents attain there. The Blanchard Race, a strait which separates the Cape of La Hogue from the island of Alderney, is the first of these terrible marine defiles where the ebb and flow, confined between chains of rocks and shallows, move at the time of high water with a speed of nearly 10 miles per hour. Then comes the strait which bears the significant name of the Déroute Passage, and in which the currents flowing along the rugged western coast of Cotentin meet those which come directly from the open sea by the breach opened between the islands of Jersey and Guernsey; there the marine rivers, less rapid, are nevertheless animated by a speed of nearly 10 feet per second. Since the disaster of La Hogue, where Tourville, unable to sail against the formidable current of Blanchard Race, lost so many of his ships, how many vessels have been wrecked, how many crews have perished, in these

terrible straits, which Victor Hugo has chosen as the theatre for his gloomy drama of *The Toilers of the Sea.*

The marine defiles which separate the British isles from the continent, and especially those of the Hebrides, the Orkney, the Shetland, Faröe, and Lofoten islands (whose rocks and shelving banks confusedly stud a very uneven sea-bed, full of abysses), are also traversed by alternate tidal currents all the more rapid and tumultuous because of the difference of level between the two sheets of water which meet in the strait. The most formidable of these passages is perhaps the Great Gulf, or "Coirebhreacain," between the islands of Jura and Scarba, on the

Fig. 42.—Course of the Tide in the Irish Sea.



western coast of Scotland. At each change in the tide a current, flowing alternately towards the mainland and towards the open sea, is produced. The English Admiralty chart estimates its speed at nearly 11 miles per hour, but sailors affirm that it is at least nearly 12½ miles, that is to say, more rapid than the stream of any continental river. No vessel can venture, in strong tides, into such a terrible race; especially when the wind blows in the contrary direction to the tide, for the Coirebhreacain is then in its entire extent a foaming "cauldron" without any visible limits.

Other tidal conflicts are hardly less terrible; such for example is that observed

in the straits of the Pentland Firth, between Scotland and the Orkneys, and which ends in the formation of currents estimated at more than 10 miles per hour. But the most celebrated of all these encounters between two tides of different levels is the Mosköe-strom, towards the southerly extremity of the archipelago of the Lofoten Islands, called also by seamen the Maelstrom. The sombre imagination of northern peoples, always tending to the creation of monsters, saw in the strait of the Mosköe-strom a polype with arms several hundred yards in length, which caused the waters to whirl in an immense eddy, in order to draw ships into it and engulf them. From this ancient legend there has even remained with many the idea that this current is a sort of abyss in the form of a funnel, which floating objects approach by degrees, forming narrower and narrower circles, till they finally plunge for ever into this revolving well. But it is nothing of the sort. The only eddies are small lateral ones, produced by the meeting of the currents, and hardly 2 or 3 yards deep. The principal phenomenon consists, as in the Coirebhreacain and the Blanchard Race, of a rapid movement of the waters tending alternately in one or the other direction, at the time of the change of the tides. When in the open sea the flow rises in the direction from south to north, a part of its mass spreads with force into the strait opening to the south, between the two islands of Mosköe and Mosköe-naes. In proportion as the surface approaches a state of equilibrium, the current, gradually weakened, tends towards the south-west and then to the west. A period of calm follows these different movements of the waves, when the level is perfectly established; but soon the ebb commences, and tends in an inverse direction, at first towards the north, then towards the north-east and east. Thus in the space of one tide the waters are alternately carried, though with varying force, towards all the points of the compass.

The tidal currents which occur at the entrance to rivers frequently give place to tumultuous movements less terrible, it is true, than those of the races in archipelagos, but sometimes of an equally striking aspect. These phenomena are known under the name of the "bore," *barre*, "eager," or *mascaret*.

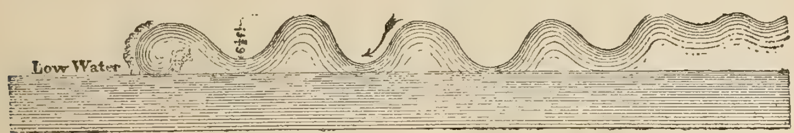
In penetrating into the estuary of a river, the tidal wave, retarded by the shallows and narrowed by its banks, must necessarily swell because of the restriction of the liquid mass in its bed. All the inlets and bays into which the tide penetrates present thus the spectacle of the "bore;" but in many passages the regular inclination of the bed, the uniformity of the shores, or else an intersection of various currents, diminish the first undulation of the tidal wave, or permit it to be confused with other irregularities of the surface. Elsewhere, on the contrary, all the topographical conditions are found united to give a great height to the "bore," and it then rises like a moving wall from one shore to the other of the estuary. At the mouths of certain rivers, such as the Amazon, the Hooghly, the Seine, the Dordogne, the Elbe, and the Weser, the waves of the "bore" assume enormous proportions at the time of high tides, and become formidable phenomena. In the Amazon, the "bore," called *pororoca* because of the roaring of its waters, rises, it is said, in three successive waves, attaining together from 30 to 50 feet in height; and vessels, surprised by this sudden flood, are in great risk of capsizing as in the open sea.

At the mouth of the Ganges the "bore" is also very formidable. As the old Hindu legend says, in symbolic language, Bagharata having taken the divine Ganga as his spouse in the midst of snows, raised her in his arms, and, mounting his chariot, traced with its two large wheels the banks of the wide bed of the goddess. But when they arrived at the seashore Ganga recoiled with affright

before the impure and monstrous ocean; she fled abruptly by a thousand channels, and since that epoch she comes and goes by turns, now venturing to descend, and now fleeing again towards the mountains, twice a day.

It is in the bay of the Seine that the *mascaret*, or "eager," has been most regularly and carefully observed. Flowing from the open sea with a speed of from 15 to 20 feet per second, the liquid wall remains curved towards the centre, under the pressure of the fluvial current. The two points of the enormous crescent break in foam on the shores; while in the middle of the concavity, the even, rounded wave advances without even rippling the water before it. It seems to turn on the river like a gigantic serpent, rising from 6½ to 10 feet above the liquid plain;

Fig. 43.—Profile of a Tidal Wave observed at the Mouth of the Seine.



whilst behind it rise waves or *éteules* in concentric undulations quite as high, the advanced guard of the tidal mass. All the obstacles placed in the way of the *mascaret* irritate it by increasing its impetus; at length the tide, entering a wider and deeper part of the bed, gradually calms and moderates its height, till it meets with another shallow or promontory. Moreover, each tide-wave is distinguished from the preceding by reason of the difference of winds, currents, and the masses of water put in motion. There is nothing more curious than to see, from the height of a promontory, two waves repelled obliquely by the banks crossing their furrows and their *éteules*.

The sole means of diminishing the force of the *mascaret*, which in several estuaries, and especially in the bay of the Seine, is sometimes dangerous to small vessels, is to regulate the channel by deepening the shallows and straightening the

Fig. 44.—Height of the Bore or Tidal Wave observed between Caudebec and Meilleraye.

banks. The works which insure a freer and deeper channel for navigation, are those which prevent the injuries caused by the great violence of the tidal waves. The *mascaret* of the Seine disappeared recently for some years, owing to the elevation of a bank of sand like a dike which prevented the entrance of the tide into the bed of the river. The encounter of the *mascaret* and the fluvial current have again raised this bank of sand at a little distance. On striking against this new obstacle, the tidal wave rises up to surmount it. Different hydraulic works, undertaken in the beds of the Garonne and the Dordogne above the Bec d'Ambez, have also often modified the phenomena of the *mascaret* there.

The sudden appearance of the tide in estuaries raises the fluvial waters very rapidly from the level of low to that of high water. At Tancarville, which is the precise spot where the Seine discharges itself into the bay, and where the tide exceeds a mean amplitude of about 13 feet, the entire rising of the waters is accomplished in two hours, while the fall of the liquid mass, driven back by the tide,

occupies about ten hours. The river having to discharge during the period of ebb not only that which the flow had brought to it, but also the fresh waters from higher up, must follow its normal course towards the sea during a space of time longer than that in which it is driven back by the rising tide. For each point of the river-bed the duration of the flow is generally the shorter the farther that point

Fig. 45.—Plan of the Tidal Wave observed in the Narrows of the Seine.

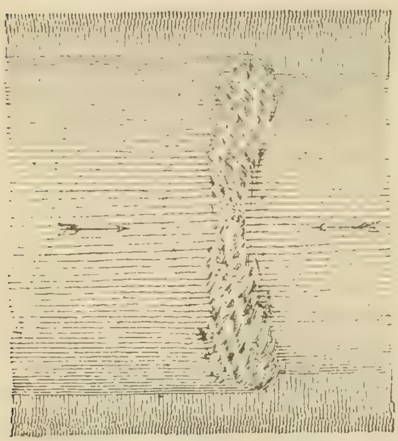
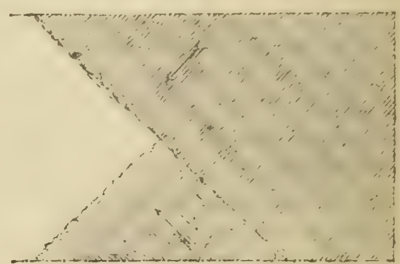


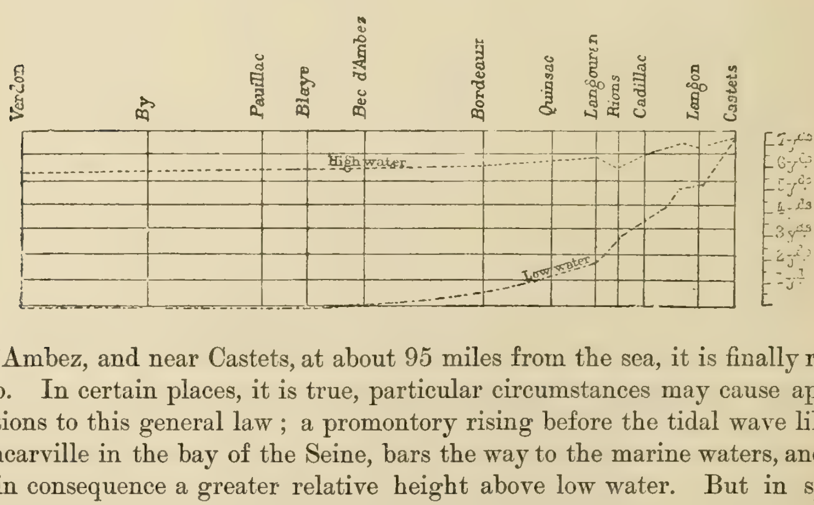
Fig. 46.—Plan of two Tidal Waves crossing each other's course on the Banks at the Mouth of the Seine.



is from the sea: the force of the tide is gradually exhausted, and towards the end of its course it only momentarily retards the speed of the fluvial current.

The amplitude of the tides diminishes, likewise, in proportion to their progress up the stream in rivers. The mass of fresh water flowing incessantly within the channel prevents the low tide from sinking as it does on the sea-shore; and as to the high tide, its shorter duration does not allow it to rise to a much higher level than that which it attains on the strands and cliffs by the ocean. Thus, in the Garonne, the difference between the ebb and flow diminishes gradually above the

Fig. 47.—Tides of the Garonne.



Bec d'Ambez, and near Castets, at about 95 miles from the sea, it is finally reduced to zero. In certain places, it is true, particular circumstances may cause apparent exceptions to this general law; a promontory rising before the tidal wave like that of Tancarville in the bay of the Seine, bars the way to the marine waters, and gives them in consequence a greater relative height above low water. But in spite of these abrupt projections, the mean amplitude of the tide diminishes from the lower to the upper course, and finally it becomes imperceptible.

CHAPTER XV.

EBB AND FLOW IN LAKES AND INLAND SEAS.—CURRENTS OF THE EURIPUS.—SCYLLA AND CHARYBDIS.

THE attraction of the sun and moon act no less on enclosed seas than on the great ocean; but in basins of small extent, the tide has not the necessary space to rise and develop itself in an appreciable manner. In Lake Michigan, which although not less than 56,000 square miles in extent, is the smallest surface we are acquainted with where the regular return of the ebb and flow have been established with precision, the amplitude of the tide is, according to Lieut. Graham, less than three inches. Still, it is undoubted that the smaller lake-basins also experience normal oscillations every twelve hours; measures carefully made will probably reveal them one day.

Even in the vast Mediterranean the tides are very little perceived, excepting in the Gulfs of Syrtes, between the ancient Pentapolis and Tunis. In this part the phenomenon of the ebb and flow occurs with the greatest regularity, and one can study its progress as in the ocean. At the mouth of the Wed-Gabès, almost at the end of the Lesser Syrtis, the water alternately rises and falls at least 6½ feet. More to the north, in the port of Sfax, the average difference between high and low water is about 5 feet, but at the epoch of the equinoxes this difference attains to nearly 8 feet. Finally, at the Island of Jerbah, the ancient island of the Lotophagi, the mean amplitude of the tide is not less than 9 feet 10 inches. This remarkable height of the tide on the shores of the Syrtes doubtless arises from the Mediterranean presenting in its southern part, from Port Said to Ceuta, a single basin, with a slightly sinuous bank, while on the coast of Europe it is divided into a number of smaller seas, those of Sardinia, the Adriatic Gulf, the Ionian Sea, and the Archipelago. Besides, the winds being much more regular on the African coast, the alternate play of the tides is not disturbed there, as on the coasts of Europe, which belong to the zone of variable winds.

However, an attentive examination of the movement of the waves has equally revealed to observers the existence of the tidal wave in the partial basins of the northern shores of the Mediterranean. Beyond Malaga, where the tides of the Atlantic are still propagated, the level of the sea hardly changes, but on the coasts of Italy the oscillations begin to be perceptible again. At Leghorn, the tide rises less than twelve inches; at Venice the difference between the high and low waters varies from one to three feet. At the mouths of the Po the tide does not attain the same height. On the coasts of Zante, in the Ionian Sea, it is less than six inches; finally at Corfu, it does not exceed an inch. In the Oriental basin of the Mediter-

ranean, the tide is likewise very slight; nevertheless, the alternate oscillation of the sea is not ignored by the people living on the shores. Omar spoke doubtless of the tide when he said, 'The sea stands very high, and day and night it entreats the permission of God to inundate the land.' A legend quoted by the traveller Maltzan tells us how the houses situated on the sea-coast rose and fell alternately, until a siren, captured and changed to a woman, consolidated the ground by planting or cultivating the seaboard.

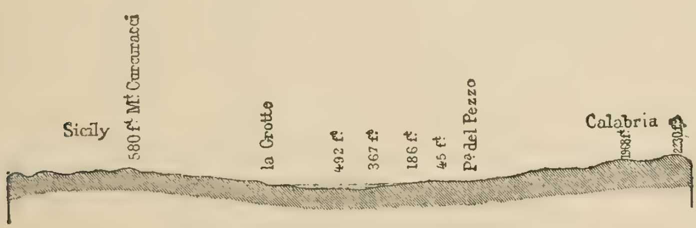
Not only has the Mediterranean its ebb and flow like the ocean, but it has also its currents and eddies, and among these phenomena, there are some which, without being as formidable as the Mosköe-strom or Blanchard Race, are not less celebrated, because of the glory with which classical antiquity has invested them. Thus, the Euripus, or Strait of Egripos, which separates the Island of Negropont from continental Greece, is said to be traversed by extraordinary currents, which produce with regularity their surprising phenomena. Up to the eighth day of the lunar month, the ebb and flow, whose mean amplitude is less than a foot, follow one another in a normal manner, only with one hour's delay; but from the ninth to the thirteenth day the movement of oscillation is suddenly hastened, and during the twenty-four hours no less than twelve, thirteen, or fourteen tides may be counted, each one having its flow, its period of stability, and its ebb. From the fourteenth to the twentieth day, a normal state of things prevails; then from the twenty-first to the twenty-sixth, every day will again be marked by a series of a dozen high and low tides. Such is the result of the experiences of the millers, who see the wheels of their mills turn alternately one way and the other, according to the direction of the current. On their side, the Mussulmans maintain, as an article of faith, that the five waves of the Euripus regularly follow the five hours of prayer; finally, the rapid observations of several travellers describe in still another manner the oscillations of the sea in the narrow channel. The fact is, that the currents of the Strait of Negropont are unexplained, and if they succeed one another in as strange a manner as the inhabitants of those shores affirm, one would really comprehend the legend, according to which Aristotle, after having vainly sought to divine the mystery, plunged in despair into the whirlpools of the Euripus. Nevertheless it appears from the observations hitherto taken that the tidal stream is always regular at the new and full moon, when it rises from one to two feet. The iregularities occur only during the intermediate quarters, that is, when the influence of sun and moon is partly neutralised. M. Forel attributes these currents of the Euripus to causes analogous to those producing the *seiches* of the Lake of Geneva. In fact the Gulf of Talanti, north of the Euripus, is a true lake, communicating with the sea only at its two extremities. Hence changes of level similar to those of the Swiss lake may be produced by the varying pressure of the atmosphere.

Still more famous than the currents of the Strait of Eubœa were the abysses of Scylla and Charybdis, braved for the first time by the wise Ulysses. According to the Homeric chants, the two howling monsters which guarded the entrance to the Straits of Messina, drew into their submarine caverns immense whirlpools of water, which they afterwards discharged in furious currents, and all the ships which approached those formidable caverns were inevitably engulfed. At present there are no straits in the Mediterranean more frequented than those of Messina, and owing to the soundings effected in these pretended abysses where the ancients saw the navel of the sea, the monsters have lost their terrible prestige. It is now known that the whirlpools of Charybdis and Scylla are nothing else than lateral movements produced by the ebb and flow, in their passage through a too narrow

channel, whose width is hardly two miles, and which the conquerors of Sicily have more than once crossed by swimming on their horses. At the time of the rising tide the current tends to the north from the Ionian to the Tyrrhenian sea; at the fall of the tide, the stream coming from the north assumes the preponderance, and drives the contrary current towards the south. But there is a strife between two liquid masses, and the field of battle moves incessantly from Messina to Scylla. On the confines of the current, where the mingling of the waters is effected with violence, narrow eddies are formed, where the waves are more agitated than elsewhere; these are the "eyelets," or *garofali*. Ships avoid them, for fear of being too violently shaken; but they run no danger unless the wind blows strongly in a contrary direction to the tide. The strait is a curious spectacle, seen from the height of the mountains of Messina or Reggio, with the undulations and eddies that the conflicting waters describe; every instant sheets of water of a darker tint than those of the surface are seen to change their form, indicating the ebb and flow.

In the other enclosed seas of Europe the tides are likewise little felt. They are less than sixteen inches on an average in the Zuyderzee, and during the days of the equinox or of tempests they hardly attain three feet six inches. The Baltic, which is much narrower and more strewn with islands than the Mediterranean, is subject in consequence to much slighter oscillations; it was even called in former times

Fig. 48.—Profile of the Straits of Messina.



morimarusa (*mor y marb*), that is to say, in the Celtic language, "Dead Sea." The sailors pay no attention to the variations of the surface produced by the ebb and flow: for them the winds, the currents, and the meteorology of the atmosphere are the only phenomena which they have to observe. In fact, on the western coast of Jutland, the tide is on an average less than twelve inches, at the entrance to the Cattegat it loses still more in force and regularity, and in the straits of the Sound and the two Belts it is difficult to recognise. In the harbour of Copenhagen an oscillation of about one or two inches can still be sometimes distinguished, but only when the weather is perfectly calm and the surface of the water hardly rippled. At Wismar the phenomena of the tide are still more uncertain, and it is only by a series of observations on the surface of the waters pursued during several years, that the probable existence of a total variation of little more than three inches between high and low water can be ascertained. Near Stralsund the difference is only one and a half inch, and near Memel it hardly exceeds an inch. The much more considerable variations which occur in the level of the sea arise from the winds, the currents, or the pressure of the atmosphere. Rapid oscillations of nearly three feet have been sometimes seen to occur; but these are the *seiches*, similar to those of the Lake of Geneva. The force of the winds alone is sometimes sufficient to lower by little more than three feet the level of the sea in certain straits, as well as in the gulfs of Esthonia and Finland.

The laws of the phenomena of the mouths of rivers differ entirely in the seas

with strong tides, as the northern Atlantic, and in those with insensible oscillations, like the Baltic and the Mediterranean. In the estuaries where the sea rises regularly twice a day to a great height, it passes over every obstacle, bars, or sandbanks, accumulated at the entrance to the mouths of rivers; while in those places where the level of the sea remains always the same, the dikes of mud or sand deposited parallel to the coasts between the fresh and salt waters, always close the entrance to the river. Thus the Rio Magdalena, and the Atrato, in the Caribbean Sea; the Rhone, the Po, and the Nile in the Mediterranean, spread their liquid mass over bars which are often hardly a yard deep at the lowest part; while the river of the Amazons, the St. Lawrence, the Gironde, and the Thames, allow free passage to ships at all hours.

This diversity of fluvial laws, according to the height of the oscillations of the tide, has the most important consequences for the commerce of regions watered by great rivers. In general the ports of the rivers without tide cannot be established at the mouth itself, because of the want of water, and merchants are obliged to choose a locality situated on the sea-coast at a certain distance from the sandy mouths of the river for their emporiums. Thus Marseilles, where almost all the commerce of the great basin of the Rhone is transacted, is constructed on the shores of a deep bay of the Mediterranean, far from the peninsulas of mud between which the river discharges itself. Alexandria, the great port of the Egyptian delta, lies to the west of the alluvial delta of the Nile; Venice is far from the mouths of the Po; Leghorn protects its port from the approach of the Arno; Barcelona is not at the entrance to the Ebro; and Carthagena in the West Indies and Santa Marta are only in communication with the great Magdalena by means of hardly navigable canals. The exceptions to this rule are not very numerous; still we may cite Dantzig on the Vistula, Stettin on the Oder, and Galatz on the Danube.

In seas with high tides the principal ports are found, on the contrary, not on the maritime coast-line, but on the rivers, and even at a certain distance from the mouth, not far from the place where the tide rises twice a day, thus changing the river into a true maritime gulf. London, Hamburg, Nantes, Bordeaux, Rouen, and many other great commercial cities, have been gradually built, in consequence of the necessities of commerce, as far as possible inland, at the precise spot where the depth of water and the force of the tide allow ships to approach easily. Nevertheless, since the ships of the present day draw much more water than those of our ancestors, the result is that a number of ports on rivers have become insufficient. It is thus that Rouen has been gradually replaced by Havre as the port for international commerce. Nantes, also, has seen in these days a rival city grow up at S. Nazaire, a few years ago an obscure village at the mouth of the Loire. Perhaps the hamlet of Verdon, provided sooner or later with docks, basins, and jetties, will become likewise the real commercial Bordeaux.

CHAPTER XVI.

INCESSANT MODIFICATIONS OF THE COAST-LINE.—THE FJORDS OF SCANDINAVIA AND OTHER COUNTRIES NEAR THE POLES.

THE sea, every wave of which contains perhaps thousands of living organisms, seems itself to be animated by a vast and mighty life. Ever-changing hues, dark as fog or brilliant as the sun, pass over its immense extent; its surface ripples in long undulations, or rises in bristling waves; its shores are touched with a border of foam, or disappear under the white mass of breaking surf. Sometimes it breathes a scarcely audible murmur, and again it combines in very thunder the roarings of all its waves dashed and broken by the tempest. By turns it is smiling and terrible, gracious and formidable. Its aspect fascinates us; and as we walk along its shores, it is impossible to avoid contemplating and interrogating it ceaselessly. Ever moving, it symbolizes life, in distinction to the silent and passive earth which it assaults with its waves. And besides, is it not always untiringly at work to modify the contour of the continents, after having once formed them layer by layer in the depth of its waters?

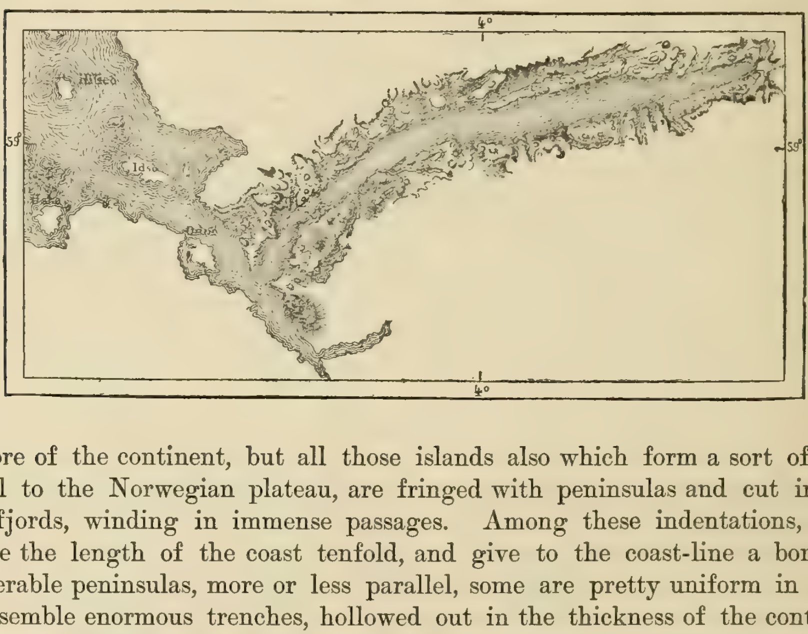
The most important part of the geological labours of the ocean is hidden from our eyes; for it is at the bottom of its abysses that the sea deposits the silica, limestone, chalk, and conglomerates of every kind which will one day constitute new lands. But at least we can witness the continual modifications to which the incessant movement of the sea subjects the shores. These modifications are considerable, and during the historical ages a number of coasts have already completely changed their form and aspect. Promontories have been razed, while at other parts points have advanced into the waves; islands have been transformed into reefs; others have been entirely swallowed up; others again joined to the mainland. The sinuous line of the shore has not ceased to oscillate, encroaching here on the waters of the ocean, and there on the continental surface. The action of the sea is double: it is constantly re-touching the contours of its basin, either by wearing away the rocks that border it and carrying away the strand, or by casting upon its coast the alluvium and wreck of every kind that it tosses in its waves. All that it engulfs on one side it gives back elsewhere under another form.

Before the sea had modified its shores by destroying peninsulas and filling up bays and estuaries, the form of the coast was certainly much less regular than it is now in the outline of most countries. If the marine waters were raised by a sudden revolution to 100 or 200 yards above their present level, the ocean, inundating all the river valleys to a very great distance from the present shores, would suddenly enter in elongated gulfs into the depressions of the continent, and change all the

valleys and lateral gorges into bays. In the place of each of those river-mouths which hardly indent the normal line of the coast, deep hollows would be opened, dividing into numberless ramifications. But a work in the opposite direction will instantly be commenced, when this change in the outline of the shores is accomplished. On the one side the watercourses, bringing down their alluvium, will gradually fill the upper valleys, and little by little restrict the domain of the maritime conquests. On the other side, the ocean will also labour by its dunes along the coast, its banks of sand or shingle, to take away from its surface all those new bays that the sudden increase of its waters had given it. After an indefinite lapse of centuries the shore would finally reassume the gently undulated form that the greater number of coasts now present.

There are still many countries where this double work of the sea and the continental waters has hardly commenced. Those lands whose coast-line, thus preserving its first form, is still deeply indented, are all situated at a great distance from the equator, in the neighbourhood of the polar zone. In Europe, the western coasts of Scandinavia, from the promontory of Lindesnaes to the North Cape, are jagged by a series of these *fjords* (firths), or ramified gulfs, and not only

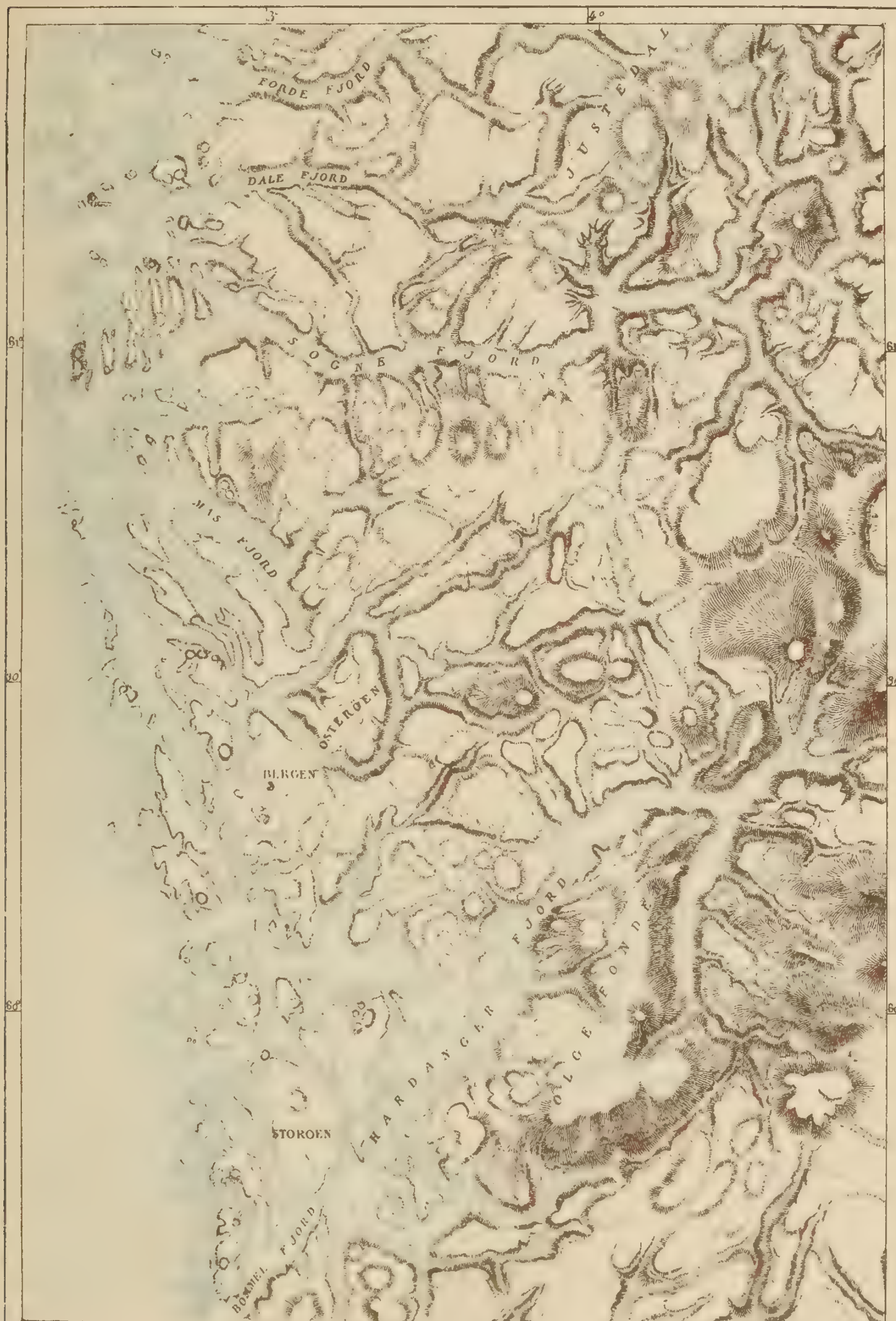
Fig. 49.—Lysefjord, Norway.



the shore of the continent, but all those islands also which form a sort of chain parallel to the Norwegian plateau, are fringed with peninsulas and cut into by small fjords, winding in immense passages. Among these indentations, which increase the length of the coast tenfold, and give to the coast-line a border of innumerable peninsulas, more or less parallel, some are pretty uniform in aspect, and resemble enormous trenches, hollowed out in the thickness of the continent; others are divided into several lateral fjords, which make the inland waters an almost inextricable labyrinth of channels, straits, and bays. The total development of the coasts is so much increased by these indentations, that the western shore of the peninsula, whose length in a straight line is about 1180 miles, is increased to above 8000 miles by the bends and turnings of the shore, which is more than the distance from Paris to Japan.

The plateaux of Scandinavia, terminating abruptly above the North Sea the slopes which command the sombre defiles of the fjords, are almost always very steep; there are some which rise in perpendicular or even overhanging walls, serving as a pedestal to high mountains. It is thus that the Thorsnuten, situated to the south of Bergen, on the shores of the Hardanger Fjord, attains an elevation

FJORDS OF SOGNE AND HARDANGER IN SOUTHERN NORWAY.



1
1.250000
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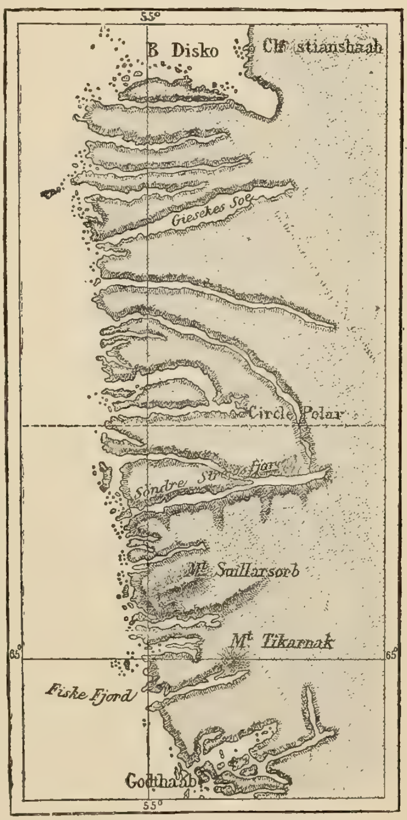
0 5 10 20 30 40 50

of above 5250 feet at less than $2\frac{1}{2}$ miles from the shore. In many a bay of western Norway cascades are seen to leap from the top of the cliff, and precipitate themselves in one jet into the sea, so that vessels can glide between the walls of the rocks and the parabola of the roaring cataracts. Below the water the escarpments are continued also in most of the gulfs, so that in certain defiles of rocks, whose breadth from cliff to cliff is only from 300 to 600 feet, the lead must be thrown to a depth of from 272 to 327 fathoms before touching the rocky bottom. In the *Toilers of the Sea* Victor Hugo correctly cites the Lysefjord as most fearful to contemplate amid its gloomy approaches, many of which are for ever deprived of a ray of sun by the high walls of rock which enclose them. This enormous cutting, of an almost perfect regularity, penetrates above 26 miles into the interior of the continent, though in several places it hardly exceeds 1965 feet in breadth; its walls rise from 3270 to 3600 feet in height, and near the edge the lead only touches the ground at about 220 fathoms. Doubtless the first seaman who sailed over the dark, tranquil waters of this abyss must have advanced with a sort of horror, asking at each new turn of the approach whether he was not going to see some terrible god rise before him. Even now it is not without a shudder that one penetrates into this gloomy defile, where the ancients would doubtless have seen the entrance to the infernal regions.

Fig. 50.—Fjords of Greenland.



The latest and most important researches on the formation of the Norwegian fjords are those of Mr. Karl Pettersen, who communicates his views and conclusions to *Nature* for June 25th, 1885. "In order to understand the subject," he remarks, "it is necessary to explain the orographical conditions along the course of the travelled blocks from the Swedish frontier to the Arctic Ocean. From the eastern end of the Alt Lake, near the Swedish frontier, and northwards to the Store Rosta Lake, the country on the Norwegian side assumes the form of an extensive alpine plateau, with broad depressions, the average height of which is about 2000 feet, running between low rounded ridges. In the south-eastern part of these plateaux, not far from the eastern end of the Alt Lake, the Divi River rises. Having for some 10 geographical English miles followed the plateau, this river flows gradually towards the Divi Valley, which it enters and follows throughout its whole course in a north-easterly direction, flowing eventually into the Maals River at a height of 260 feet (82 mètres) above sea-level. Its length, from where it leaves the plateau to the spot where it joins the Maals River, is about 30 geographical miles. In its upper course, where the Maals River receives the Divi River, the former flows through a wide plain or low plateau, the so-called Överbygd, which gradually slopes down to a distinct valley, the Maals Valley

proper, which runs in a westerly direction along the southern slope of the high, island-shaped mountain ridge called Mauken. The latter begins about 5 miles west of the spot where the Divi River enters the Maals River, whence it runs in a direction east-west for a length of about 15 geographical miles, the highest tops being upwards of 4000 feet (1255 mètres). On the north-western side, however, the Överbygd gradually rises towards the broad mountain depression filled by the Tag Lake, 7 miles in length, which runs in a direction east-west along the northern slope of Mauken, viz. between the latter and the more northerly lying ridge Omasvarre, which, with tops upwards of 1900 feet (596 mètres) in height, also runs in a direction east-west. The bottom of this depression is filled with the imposing Tag Lake, which lies on a height of about 600 to 700 feet (188 to 220 mètres) above sea-level, and thus about 400 feet (120 mètres) higher than the Divi River at the spot where it enters the Maals River. At the western end of the Tag Lake this depression takes the form of a broad mountain basin, the so-called Tag Valley, which, in a north-easterly direction descends to Balsfjord. The distance between the Tag Lake and the Balsfjord is about 10 geographical miles. The Tag Valley is, on the western side, bordered by the lofty Maartin peaks, and further to the north-east by the Slet Mountain, which, like an arm of the Maartin peaks, gradually slopes down to the Balsfjord.

"The line of depression from the spot by the frontier where the Divi River rises, to the bottom of the Balsfjord which we have thus followed, is about 50 geographical miles in length. The course of the Balsfjord is north-westerly, but very crooked, between mountains upwards of 4000 feet (1255 mètres) in height. The latter are, however, not continuous, but separated into island-like parts by deep depressions, which, in a recent geological period, when the level of the sea was 300 to 400 feet (91 to 126 mètres) higher than at present, must have been submerged, thus making each part an island. In spite, therefore, of the typical fjord character of the Balsfjord, it was originally only a number of sounds, by which it was once connected with the Malangen Fjord on the western, and the Sörfjord, Ulfsfjord, and Lygenfjord, on the eastern side. This is a circumstance of great orographical importance, and which deserves every attention, particularly because it does not apply to the Balsfjord alone, but is a characteristic of the formation of every fjord in the north of Norway, from Salten (Bodö) in the south to Lyngen in the north—*i.e.* from 67° to 70° N. lat.

"From the bottom to the mouth, in a sound between the mainland and the south-eastern side of the great island, Kvalö, the length of the Balsfjord is about 30 miles. At the Troms Island, which lies about five miles to the north of the mouth of the Balsfjord, this sound is divided into two narrow sounds, about five miles long, on each side of the Troms Island. From the northern point of this island these sounds reunite, and the sound becomes the broad Gröt Sound on one side, which, running in a northerly direction, joins the Ulfsfjord at its mouth by the Fugle Sound—a broad arm of the sea cutting into the land. On the other side, the sound is also connected with the open sea by the Kval Sound, 10 to 15 miles long, which runs in a westerly direction, between the two great islands Kvalö and Ringvadsö. The length from the mouth of the Balsfjord to the end of the Kval Sound by the ocean is about 30 miles, or about the same as the length to the end of the Gröt Sound. Thus, from the bottom of the Balsfjord to the sea the distance described is about 60 miles.

"As regards the depth of the Balsfjord and the adjacent sounds, it may be mentioned that that of the former varies from 80 to 100 fathoms (480 to 600

feet = 151 to 188 mètres), but from the mouth of the fjord towards the Troms Island the depth steadily decreases, being, in the sounds on both sides of it, not more than 20 to 30 fathoms (120 to 180 feet = 38 to 56 mètres). To the north of this island, in the Gröt Sound, on the other hand, the depth increases to 100 or 120 fathoms. In the eastern half of the Kval Sound the depth is from 20 to 30 fathoms, while in the western half it reaches, at the mouth, 120 fathoms. It will therefore be seen that the depth of this channel in the main increases seawards, if we except the two places by the Troms Island and in the Kval Sound, the shallowness of which may be caused by narrowness of the sounds, and the consequent opportunity for the deposit of marine débris.

"Thus, the entire length of the line of depression we have examined, from the sources of the Divi River to the ocean, is 96 geographical miles, while the bottom of the same falls from 2000 feet above the level of the sea to 720 feet below it—*i.e.* a total fall of 2720 feet.

"The geological structure of the mountains here is very remarkable. A large mass of granite which appears at each end extends inland far into Sweden, and, on the Norwegian side, reaches the upper Divi Valley. The rock is composed of orthoclase, microlin, plagioclase, a great deal of quartz, but very little mica. The colour is reddish, the structure granulated. At the other end of the line we have followed, on the Kvalö and Ringvadsö Islands, there are several masses of a grayish, streaky gneiss-granite, rich in mica, closely allied to the gneiss-masses found here. Petrographically, the Divi Valley and the coast granites are so different, that it seems at first sight very easy to distinguish them, but this is not so easy with the variations of the two kinds.

"The mountains which project into these granite-masses are built of layers of crystalline slate, and travelled blocks of this material may be found everywhere; but as it would be a matter of great difficulty to refer these to their original birthplace, I shall not take them into account here. We will, therefore, only follow the course of the granite blocks travelling from the Swedish frontier to the coast.

"There are two roads by which they might have moved, viz., one from the southern part of the granite-mass along the Alt Lake to Bardö, and so on; the other more northerly, along the Divi Valley. It is the latter which I intend to discuss here.

"The above-mentioned alpine plateaux are strewn with travelled granite blocks, and that the same have travelled westwards from the granite masses by the frontier cannot be doubted. The same applies to all the blocks strewn along the Divi Valley. At the spot where the Divi River joins the Maals River the travelled blocks have followed two courses—viz., one through the Maals Valley, along the mountain Mauken—which we shall not follow—and the other in a north-westerly direction across the Overbygd to the Tag Lake, the lower parts of the Överbygd being thickly strewn with granite blocks which, judging by their petrographical composition, I am sure belong to the Divi Valley granite. Hence the course of the blocks can be traced along the depression in the mountain by the Tag Lake, not only at the bottom, but high up on the mountain sides. Thus, the northern slope of the Mauken is everywhere, up to a height of 2500 feet (784 mètres), strewn with travelled granite blocks; indeed the brink of every terrace looks—seen from below—as if it were faced with travelled blocks, which everywhere seem to belong to the Divi Valley granite. Travelled granite blocks were found, too, strewn up the slopes of the Omasvarre Mountain to a height of 1200 feet (376

mètres)—viz., as far as I was able to carry my researches. I believe they would be found right up to the top.

"From the western end of the Tag Lake the blocks have moved along the Sag Valley, and then to the bottom of the Balsfjord. The flat stretch of shore, 210 feet broad, high, and covered with loose débris, is strewn with blocks which without doubt belong to the Divi Valley granite.

"From what I have thus explained we may safely assume that an enormous mass of inland ice has once moved from the frontier through the above-described channels, down to the Balsfjord, and that it must, along the Mauken, a distance of 10 miles from the fjord, still have maintained a height of at least 2500 feet (784 mètres) above the then sea-level.

"Before we follow the course of the blocks farther, I will refer to certain circumstances connected with it thus far About five miles to the westward of the mountain plateau near the frontier rises the isolated mountain Store Jerta to a height of 4500 feet (471 mètres)—viz., about 1000 feet (314 mètres) higher than any of the surrounding mountains. The Store Jerta is throughout built of hard crystalline slate. On the very summit of this peak I found a large block of granite which I feel confident is a travelled block from the granite mass to the east of it. Its birthplace must in that case have been at least 1000 feet (314 mètres) lower, and, as the Store Jerta has been situated right in the track of the ice-stream from the east, I am of the opinion that the ice has been screwed up here to a very great height; but I confess it seems hardly possible to understand that it could be to such an enormous height.

"I have stated above that the Tag Lake lies 42 feet higher than the spot where the Divi River enters the Maals River, and supposing that this was also the case during the Glacial Age, the ice-stream must have moved up an incline before it could reach the depression leading down to the Balsfjord. This cannot, however, have been the case. As long as the ice-stream had perfect liberty to travel down an incline—here present in the shape of the broad Maals River, along the southern slope of the Mauken—it would hardly ever move in the opposite direction up an incline; leaving, however, local accumulations out of consideration. It might therefore be reasonable to suppose that the configuration of the land along the Divi Valley, and especially the Överbygd, was very different during the glacial age. A continuous, though slightly inclining surface, must under these circumstances at that period have extended from the alpine plateaux above the Divi Valley to the depression along the Tag Lake, and the present configuration be caused by subsequent erosion. It should be stated that the outlet of this lake does not now follow the course of the ice-stream towards the Balsfjord—which might have been reasonably assumed—but is at the opposite, eastern end, towards the Maals River. This seems to indicate that the present declivity of the Överbygd in an easterly direction in any case cannot be older than the close of the glacial age.

"As stated, travelled granite blocks from the Divi Valley are found in great numbers along the northern slope of the Mauken, towards the Tag Lake, upwards of 2500 feet (784 mètres); but that these should have been raised from lower levels to their present height seems improbable. The northern slope of this mountain does not lie transversely to the course of the ice-stream, but longitudinally to it. Of course the screwing up of the ice may also take place in the latter case, but I should say only in isolated spots; this cannot have been the case along the Mauken. Neither is it possible that the bottom of the lake lay at that level in the glacial age. It must then have lain lower than the alpine plateaux by

the frontier, and even if we allow for enormous glacial erosions, it would be impossible to believe that the bottom then lay at such a height. As the blocks on the Mauken cannot thus have been deposited along the bottom of the ice-stream, nor brought thither through screwing up of the ice, we must assume that they have been deposited from the surface of the ice-stream. The latter being strewn with blocks, which at the frontier was above 3000 feet (941 mètres) high, has therefore, at 40 or 50 miles therefrom, had a height of 2500 feet. The surface can, therefore, under this long journey, only have had a very small declivity outwards.

"From the western end of the Tag Lake the great ice-stream has moved forward to the Sag Valley, which, being then as it is at present, has been able to receive it and turn it in a north-westerly direction downwards to the Balsfjord. That the Sag Valley cannot be of glacial origin, produced by erosion, is clear from the very nearly acute angle it forms with the Tag Lake depression. It might also be assumed that the ice-stream here might have moved forward across the Slet Mountain and the long narrow peninsula between the Malangen and Balsfjord, but that this was not the case is proved clearly by the circumstance that travelled granite blocks are found on this peninsula only at low levels, which I shall presently explain.

"It may be probable that the ice-stream from the Tag Lake has met another descending from the Maartinder in the Sag Valley, but there is no middle moraine proving this. On the other hand, travelled granite blocks are but sparsely strewn along the north-western side of the Sag Valley, at the foot of the Slet Mountain. Should the Sag Valley, therefore, be of glacial origin, it might more naturally be attributed to the ice-stream from the Maartinder, but even then eroded before the great inland ice-stream entered it. If, however, this was the case, the former ice-stream must have been in motion long before the latter, of which there is no probability.

"We therefore come to the conclusion that the basin of the Balsfjord, viz., the Tag Lake depression and the Sag Valley, cannot be the result of the erosive action of the inland ice, but that it existed prior to the glacial age, and that, in fact, the depression in question was the cause of the ice-stream taking this course.

"We will now follow the depression through the fjord and adjacent sounds.

"As soon as we leave the true bottom of the fjord the travelled blocks are differently situated to those inland. There are plenty of granite blocks to be found, but they are everywhere confined to lower levels, viz., from the shore-line up to 120 feet (38 mètres). Above, there is none, and the line of disappearance is very marked. My researches have extended, on the eastern side of the fjord, from the bottom to the sea; on the western side, though they do not extend so far, they go to show that the conditions there are identical with those on the eastern side. It is particularly significant that neither here are the blocks found above a height of 120 feet along the low, transverse ridge which runs from the Balsfjord on one side westwards to the Malangenfjord, and on the other, eastwards to the Lyngen and Ulfs fjords. Thus, the outer Malang isthmus, which, rising slowly to a height of 400 feet (125 mètres), leads from the Bals to the Malang fjords, is along the former strewn with blocks, but only at lower levels. Above 120 feet they disappear. From this also it is clear that the inland ice cannot have moved forward across the Slet Mountain and the isthmus between the Bals and Malang fjords, previously referred to. From the bottom of the Nordkjos, a short by-fjord of the Balsfjord, running eastwards, the Balsfjord isthmus, two miles long, with a

height of 250 feet (78 mètres), leads to the bottom of the Storfjord in Lyngen. Here, too, the blocks are confined solely to lower levels towards the Nord and Balfs fjords. The blocks have not reached as far as across the isthmus to the Storfjord.

"The blocks may in the same manner be followed along the Ramfjord, which as a by-fjord runs from the mouth of the Balsfjord eastward to the Bredvik Isthmus. From the southern side of the mouth of the Ramfjord the Anders Valley runs in a southerly direction between lofty mountains and with a steady incline. Here, too, travelled granite blocks are found to a height of 120 feet, but not a single one above. The case is the same along the sounds around the town of Tromso. Further, I have followed the blocks northwards, on the mainland to Tunnes, about five miles from the town, but whether they have travelled farther along the Grot Sound I have not yet been able to ascertain. The same applies to the Kval Sound. But researches made on the islands outside this sound prove beyond a doubt that the granite blocks from the Balsfjord cannot have reached these islands by way of the Kval Sound.

"The greatest number of travelled blocks along the Balsfjord belong, judged petrographically, to the Divi Valley granite, blocks which might with certainty be referred to the coast granite not having been found. Along the sounds, too, the greatest number of blocks, if not all, may be referred to the Divi Valley granite; but blocks belonging to the gray, streaky gneiss-granite of the Kval Island are also met with here, some of which may even be referred to exact localities in the island. Among the rocks along the Troms Island and adjacent sounds blocks of a coarse-grained syenite are also often found. In the Divi valley no varieties of syenite appear, but they are often encountered combined with gneiss and gneiss-granite on the coast. Although I have not yet succeeded in finding syenite in places which with certainty can be said to be petrographically identical with that of these travelled blocks, I have every reason to believe that they hail from the west.

"We have now followed the course of the blocks along a continuous distance of 84 geographical miles—viz. 48 on the mainland and 36 on the shores of fjords and sounds.

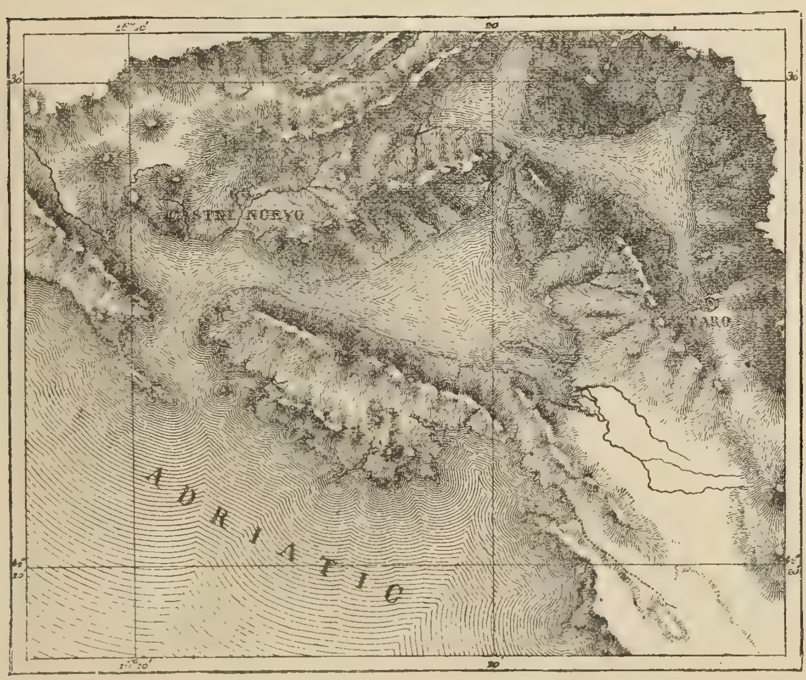
"From what I have advanced here as regards the blocks during their journey through the Balsfjord, it seems clear that their transport here cannot be ascribed to a moving stream of inland ice. The sharp line of demarcation, above which no blocks are found, seems in itself to demonstrate this. The line extending for miles along a long fjord and extensive sounds, and being so sharply defined, bespeaks that the transporting agency at work here must have been far more regular during a length of time than a stream of inland ice possibly could be. We have therefore every reason to conclude that these blocks have been carried along the level of the sea on drift-ice, *i.e.* shore-ice. As the block-transport appears from the first simultaneously along the long stretch of shore from the Balsfjord, and past the Troms Island, a strong in and out-flowing current during the diurnal tides has in all probability been at work at a period when the level of the sea was 120 feet higher than at present. And the strong drift of the ice outwards must have been stronger than the one inwards up the fjord. Travelled blocks of the Kval Island granite are, therefore, not found in the interior of the fjord, but the case is different along the broad sounds about the mouth of the fjord; here the in and out-flowing currents have had alternate sway, and here are also found blocks of the Divi Valley, as well as of the coast granite.

"There is another important circumstance which beyond a doubt proves that the inland ice during the Glacial Age cannot have moved along this fjord, scouring the

bottom. Thus, if we consider the present depth, about 600 feet, and remember that the level of the sea during the Glacial Age was about 600 feet higher than at present, and further that great quantities of *débris* must have been deposited at the bottom of the ice, it is evident that an ice-stream moving through the fjord, and a sixth part of whose volume rose above the then sea-level, must have reached several hundred feet above the former—that is, the out-gliding stream must have reached several hundred feet above 120 feet, the line of demarcation for the blocks, as it then lay at least 200 feet below the sea. If, however, this had been the case, granite blocks should now be found at a far greater height than 120 feet. Neither can the Balsfjord during the Glacial Age have formed a valley along which the inland ice might move, as, in this case, travelled blocks would have been found along the sides at even far greater heights.

"I have, therefore, after the most careful researches here, yard by yard, and

Fig. 51.—Mouths of Cattaro.



extending over many years, come to the conclusion that the Balsfjord is not of glacial origin, but formed an incision or depression in the mountains of older origin than the Glacial Age. And this conclusion I believe may, in the main, apply to the question of the formation of all fjords in the north of Norway. But whether it is applicable to all fjords in the whole of Norway I shall not attempt to answer.

"There may, however, be reason to assume that the explanation of the fjord-formation in parts which have lain under an earlier Glacial Age as being of glacial origin, is rather based on speculation than such careful and minute researches as those I have referred to here, and which may, perhaps, contribute to prove the correct theory."

The islands of Spitzbergen, Faröe, and Shetland present also in their outline

hundreds of fjords, like those of Scandinavia. The coasts of Iceland, Labrador, and western Greenland, those of the islands of the Polar Archipelago, and finally the American coast-line of the Pacific, from the long peninsula of Alaska to the labyrinth of Vancouver's Island, are no less rich in indentations than the coast-line of Norway. The shores of Scotland are deeply cut in the same way, but only on the western side, where there are besides numerous islands reproducing in miniature the maze of promontories and bays of the mainland. That part of Ireland turned towards the open sea develops itself also into a succession of rocky peninsulas, separated by narrow gulfs; but to the south and east the coasts of the British Islands are much less varied in form, and sweep in long regular curves. In

Fig. 52.—Fjords of South America.

France we hardly find a vestige of indentations like those of the Norwegian fjords, except at the extremity of Brittany; and there does not even exist a word in the language to designate them. In Spain, in the same way, the part of the peninsula turned towards the north-west, and where the ports of Ferrol and Coruña open, is the only one which presents some lines of fjords half filled up. Two countries on the borders of the Mediterranean have their coasts also cut into fjords, partially obliterated by alluvium; these are Asia Minor and Dalmatia, whose high mountains, formerly covered with glaciers, overlook narrow bays with fantastic outlines like the mouths of Cattaro; but along these two shores the peninsulas of the coast-line are still uniformly turned towards the west.

To the south of the Adriatic and the Archipelago, on the coast-line of warm or

torrid countries, no more fjords are seen. To find a similar formation of shores we must traverse the entire continent of America to its southern extremity. The fjords only commence beyond the uniform coast-line of Chili, with the Island of Chiloe, its numerous bays, and the network of straits in the Archipelago of Magellan and Tierra del Fuego. This is the only region in the southern hemisphere where the astonishing phenomenon of tortuous and deep valleys filled by the waters of the sea is witnessed. As to the countries of the Antarctic continent, no indentations can be recognised in them, since the contours of the bays and capes, the gulfs and peninsulas, are all filled by the snouts of glaciers and by continuous ice-fields.

In the polar archipelagoes whose configuration is not concealed by accumulations of snow or ice, the fjords are continued from side to side, thus affording a through passage between the islands. Such a fjord, with double entrance, is the Strait of Magellan, and in the same archipelago a large number of other secondary passages presents an analogous formation. In the same way, Novaia Zemlia is divided into two islands by the double fjord of the Matochkin-shar.

In these regions all the transitions may be observed from fjords to open straits. In many places the least change of level, the least upheaval or subsidence of the land, would suffice to unite or separate the two fjords facing in opposite directions. In the interior of regions situated under high latitudes the margins of the lakes and shores of the islands exhibit the same phenomenon, all being cut up by innumerable fjord-like inlets. Thus the lakes of Scandinavia and of North Russia, especially Onega, as well as those of North America and Newfoundland, resemble the ocean in the indented character of their coast-lines.

Royal Island, in Lake Superior, is a remarkable example of this formation. Here the deep narrow passages penetrate in parallel troughs into the interior of the island, and are continued by chains of lakes disposed in the same direction. The whole island is composed of rocky crests, which are separated by intermediate valleys terminating in fjords. But while in Norway all the fissures of the ground have been formed in different directions, the whole constituting an endless labyrinth of fjords, in Royal Island all the inlets round the coast follow exactly the same direction as the axis of the island itself, and of the western section of Lake Superior, which runs generally from south-west to north-east. This direction is also followed by the intricate archipelago of the "Thousand Islands," which lies beyond Lake Ontario at the head of the Saint Lawrence. At this point the river escapes from the lake through an ancient fjord, which extends to the gulf developed between Newfoundland and Canada.

Owing to the changes that have taken place in the land and climate, many fjords have thus been converted into rivers. But the main outlines have been so little modified that their appearance has occasionally deceived explorers. Hendrick Hudson, when he first penetrated into the river now bearing his name, fancied he had discovered a passage right across the North American continent.

CHAPTER XVII.

FILLING UP OF THE FJORDS BY MARINE AND FLUVIAL ALLUVIUM.

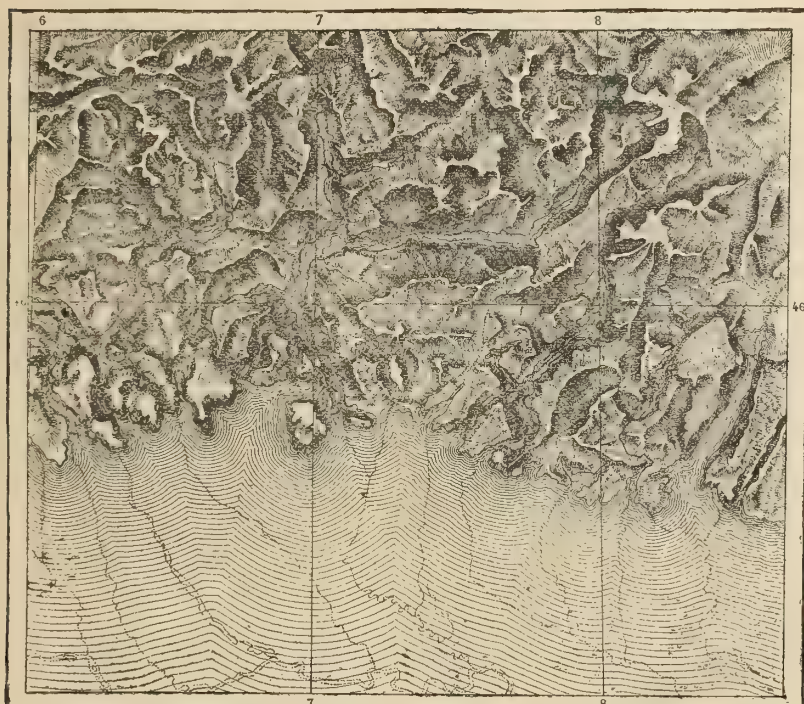
THE comparative study of all the shores leads thus to the confirmation of this fact, that fjords are only met with on the coasts of cold countries, and that, with equality of temperature, they are much more numerous and better developed on the western coasts than on those turned to the east. Why does this strange geographical contrast occur between the various shores according to the position which they occupy to the north or south, to the west or east? Why have the strands and even the cliffs, bathed by a warm or temperate atmosphere, assumed in the outline of their curves such a great regularity, while the valleys, opened in the thickness of the plateaux of Scandinavia, Greenland, and Patagonia, have preserved their primitive form? A cause whose effects are produced at the same time and in the same manner at the two extremities of the continents, in the northern islands of America and Europe and in the Magellanic Isles, must necessarily have been a great geological phenomenon, acting during an entire age of our planet.

This phenomenon was the special climate which during the glacial period made itself felt on the surface of the globe, and transformed the mountain snows into long rivers of ice. The map speaks for itself, so to say; it relates clearly how the fjords, those ancient indentations of the coast-line, have been maintained in their primitive state by the prolonged sojourn of glaciers. In fact, the cold period, the unequivocal witnesses of which are still to be seen even in the tropics and under the equator, at the foot of the Andes and in the valley of the Amazon, naturally lasted longer in the vicinity of the poles than under the torrid zone and in the temperate regions. This glacial period, which terminated perhaps thousands of centuries ago on the burning shores of Brazil and Columbia, has ceased at a relatively recent epoch on the coasts of France and England. At an age still nearer our historical time the fjords of Scandinavia have been in their turn freed from the glaciers that filled them, whilst quite in the extreme north and in the Antarctic regions there are countries where the rivers of ice still descend into the sea, and stretch far into the gulfs. The glacier of the Bay of Magdalene, which Messrs. Martins and Bravais have explored, projects far into a fjord which is 55 fathoms deep, and the terminal cliff of ice, driven out by the weight of the upper snows, presents a curved line, turning its convexity towards the open sea. On still colder coasts, such as the north of Greenland, and at the South Pole, the outline of the Antarctic countries, even the bays, are entirely filled up with ice, and this running into the sea gives a regular outline to the whole coast. The waves of the open sea dash against a long wall of crystal, and the icy layers

disguise the true form of the architecture of the continents, as the fluvial alluvium and marine sandbanks do in other climates. Nevertheless deep valleys, hidden by the ice-fields, are also cut into the line of these Polar coasts, and in a future geological period, when the ice shall have disappeared, these incisions of the continent will become, in their turn, fjords similar to those of Scandinavia

At the epoch when the bays of Scandinavia were filled with ice, as those of northern Greenland are in our days, they preserved their primitive form, excepting that the lateral walls and the rocks at the bottom were grooved and polished by the friction of the mass in movement and the fragments which it carried with it. The blocks of stone fallen on the snow, and on the surface of the glacier, the heaps

Fig. 53.—Ancient Fjords of Northern Italy.



of pebbles and earth torn by storms and thaws from the sides of the mountain, formed moraines exactly similar to those which are now seen on the diminished glaciers of the Scandinavian mountains. But these moraines, instead of crumbling away with the ice, in some valleys thousands of feet above the sea, were carried to the very mouths of the fjords in the open sea, and plunged into the middle of the waves with the pieces detached from the glacier itself. The successive débris of rocks and pebbles must necessarily gradually raise the frontal submarine moraine, and in fact at the entrance of all the Scandinavian fjords, heaps of deposit are found rising like ramparts out of the deep water. The seamen of Norway give the name of "sea gates" to these natural barricades, which serve as limits to the ancient glaciers, and where the fish from the neighbouring waters assemble in myriads. Off the coasts of western Scotland, as at the entrance to the small gulfs

of Finisterre, the ridges of submarine banks and reefs are observed, which are probably nothing else than ancient terminal glacial moraines.

After the period which preceded the present era, the glaciers of Scandinavia retreated little by little into the interior of the fjords, then ceased to touch the level of the sea, and their lower extremity mounted higher and higher in the open valleys on the sides of the mountains. It was then that the immense geological labour of filling up the bays commenced for the torrents and the sea. The fluvial waters brought their alluvium, and deposited it as an even strand at the foot of the mountains, while the sea levelled with sheets of sand or mud all the fragments of rocks which it had worn away by its waves. Already in a great number of Norwegian fjords this work of transforming the domain of the waters into firm land has made very sensible progress, and if we knew the amount per century of the augmentation

Fig. 54.—Fjords of the South-East of Iceland.

to the shores, we should be able to calculate approximately the epoch at which the valley was free from ice. On the inclined eastern side, towards the open country of Sweden, an analogous work is accomplished; there, the glaciers have been replaced, not by the waves of the sea, but by the lacustrine waters divided into different basins, and these waters also retreat gradually before the alluvium of the torrents. In the same way, in the great chain of the Swiss Alps, several deep depressions, formerly the beds of immense glaciers, have become a sort of continental fjord, such as the lakes Maggiore, Iseo, Lugano, Como, and Garda. These lacustrine basins are closed at the south by large moraines, like the sea-gates of Norway, and their waters, like those of the fjords, are gradually displaced by the alluvium brought down by Alpine torrents.

Situated more to the south than the fjords of Scandinavia, and nearer the source

of the warm current flowing from the Antilles, the western bays of Scotland must have been free from ice long before the coasts of Norway, and at a still earlier date the indentations of the coast-lines of Ireland and Brittany ceased to serve as beds to the solidified snows of the surrounding mountains. As to the shores of the British Islands turned to the east towards the North Sea, they have certainly long been freed from ice, for then as now the winds from the west and south-west prevailed in Europe, and carried the rains over the slopes of the mountains inclined towards the Atlantic ; on the opposite slope the glaciers are sooner melted, because of the want of the necessary moisture. This is the reason of the striking contrast presented in the British Isles and Iceland by the western coasts all cut into deep bays, and the eastern shores whose fjords are less deep, or even completely obliterated by alluvium. In the same way, at the south of America, the rains being much more abundant on the western slope of the mountains of Patagonia, the glaciers have

Fig. 55.—Filled-up Fjords of Christianssand.

descended much lower into the valleys, and the fjords, preserved by the ice in their primitive state, make all this part of the American coast-line a real labyrinth. The form of the continents themselves must be explained by the movements of the atmosphere.

After the retreat of the glaciers, the work of rendering the shores regular goes on in the various countries with more or less rapidity, according to the form of the continents, the depth of the fjords, and all the phenomena which constitute their geographical conditions. In certain countries where the rivers are of little importance, as in the peninsulas of Denmark and in Mecklenburg, the fjords are first closed on the seaward side, and then become long and narrow lagunes, separated from the salt waves by the sandy beaches. Those gulfs, on the contrary, where great rivers discharge themselves, are gradually filled up by alluvium in those parts the farthest from the ocean, and are changed little by little into estuaries. Finally many shores, among others those of eastern Iceland, present a great number of

fjords, one beside the other, which are narrowed at the same time above and below by the deposits from the sea, and from the streams of the interior. It is thus that a multitude of ancient gulfs in Scandinavia, England, and France, have been gradually changed into dry land. The gulfs of Christianssand in Norway, of Carentan in France, formerly projected in all directions from deep abysses, the place of which is occupied now by fields and marshes.

Whatever may be the diversity of means employed by nature in filling up the ancient glacial bays, the labour is accomplished in due time, and we may state that from the temperate to the equatorial zone the curves of the shore increase in regu-

Fig. 56.—Ancient Fjords of Carentan.

larity. The innumerable ports which penetrate deep into the northern lands are succeeded in the south by more and more inhospitable maritime shores, because destitute of indentations. And on the coasts of the torrid zone, which are destitute of the mouths of rivers, vessels must sail along for hundreds of leagues before finding a harbour of refuge. It is the three southern continents, South America, Africa, and Australia, which present in their outline a most uniform development of coast and are most destitute of bays.

If we can rightly consider each glacier as a natural thermometer, indicating by its advance and retreat all the changes of local temperature, we may in the same way

regard the general character of the coasts, from the fjords of Greenland and Norway to the long shores of equatorial Africa, as a visible representation of the changes of temperature which have taken place on the surface of the globe since the Glacial Epoch. If by long and patient study we succeed in measuring the time which is necessary for the alluvium of the sea and rivers thus to modify the forms of valleys once filled with ice, we can then estimate the amount of time which has elapsed since the Glacial Epoch. This vague period, which according to various geologists comprehends thousands or millions of years, will assume, at least for the times nearest to us, a more precise meaning, and will arrange itself like the centuries in the chronology of mankind.

CHAPTER XVIII.

DESTRUCTION OF CLIFFS.—THE COASTS OF THE CHANNEL.—THE STRAITS OF DOVER.—ACTION OF SHINGLE AND SAND.—GIANTS' CAULDRONS.—SPOUTING WELLS ON THE COASTS.—TIDAL WELLS.

ALTHOUGH there is necessarily an equilibrium between the work of demolition and that of reconstruction, we would nevertheless at first sight be tempted to believe that the sea took the greatest pleasure in destruction. On contemplating the cliffs, those perpendicular walls which on various coasts rise many hundreds of yards above the level of the sea, we are struck with awe to see how the repeated assaults of the waves have been sufficient thus to cut the mountains and hills whose bases were formerly gently sloped to the water. From the top of these cliffs, we see the tumultuous ocean spread at their feet like a plane surface, and we no longer distinguish the billows but by their reflections, or the breakers but by their garland of foam; the multiplied sound of the waves melts into one long murmur, which dies away and rises to die away again.

And yet this water, which we see below at such a great depth, and which seems powerless against the solid rock, has thrown down piece by piece all that part of the hill or mountain, of which the cliff is but a gigantic memorial; then, after having thrown down these enormous masses, it has reduced them to sand, and perhaps caused the very trace of them to disappear. Often not even a rock remains where promontories once jutted out. The phenomena ascertained even during the short life of man, are facts so grand in their progress, and so remarkable in their effects, that an English savant, Captain Saxby, has proposed to make of them a special science, *Undavorology*.

In February, 1870, a cliff in the territory of the Dahra tribe, on the Algerian coast, gave way bodily, bringing down at least 123,000,000 cubic feet of matter, and filling up a little haven where the small Spanish coasters used to ride at anchor.

To gain some idea of the destructive force exercised by the waves of the ocean, it is sufficient to contemplate them on a tempestuous day from the height of the chalky cliffs of Dieppe or Havre. At our feet we see the army of whitening billows rush to the assault of the rocks. Driven at the same time by the wind, the tide, and the lateral current, they leap over the rocks and shelves of the shore, and strike the base of the cliffs obliquely. Their shock causes the enormous walls to tremble to the very summit, and the roar reverberates in all their angles with an incessant thunder. Dashed into the fissures of the rock with terrible force, the water sweeps away all the clayey and chalky matter, and gradually lays bare the

solid beds, wrenches large blocks out of them, rolls them on the strand, and breaks them into shingle, which it drives along with a tremendous noise. Through the eddy of boiling foam which besieges the shore, one can only now and then perceive the

Fig. 57.—Roads of the Downs.

work of demolition; but the waves are so laden with fragments that they present a blackish or earthy colour, as far as the eye can reach.

When the storm has ceased, the encroachments of the sea can be measured, and we can calculate the millions of cubic yards of stone engulfed or transformed into shingle and sand. Towards the end of the year 1862, during one of the most terrible tempests of the century, M. Lennier saw the sea batter down the rocks of

La Hève to a thickness of more than 50 feet. Since the year 1100, the waters of the Channel, aided by rain, frost, and other agents that act strongly on the upper strata, have cut down this cliff by more than 1500 yards; that is to say, more than two yards per year. The spot where the village of Sainte Adresse formerly stood has given way before the flood, and is replaced by the bank of l'Eclat. M. Bouniceau, one of those savants who have specially studied the phenomena of erosion of shores, estimates the fraction of cliff which is carried away by the sea on the coasts of Calvados at above a quarter of a yard on an average yearly, while on the coasts of Seine Inférieure the annual erosion may be considered as nearly a foot.

In some places on the southern and eastern coasts of England, the invasions of the sea take place with an equal or even superior rapidity, for the farmers generally count on the loss of about a yard per year along the cliff. To the east of the peninsula of Kent, the waters have advanced more than 3 miles towards the west since the Roman period. In their successive invasions, they have submerged the vast domains of the Saxon Earl Goodwin, and have replaced them by the terrible Goodwin Sands, where so many ships are lost every year; and they have transformed the narrow lagune of the Downs into great open roads. According to the calculations of M. Marchal, the total amount of denudation which the waters of the eastern part of the Channel carry on every year is equal to above 13,000,000 of cubic yards.

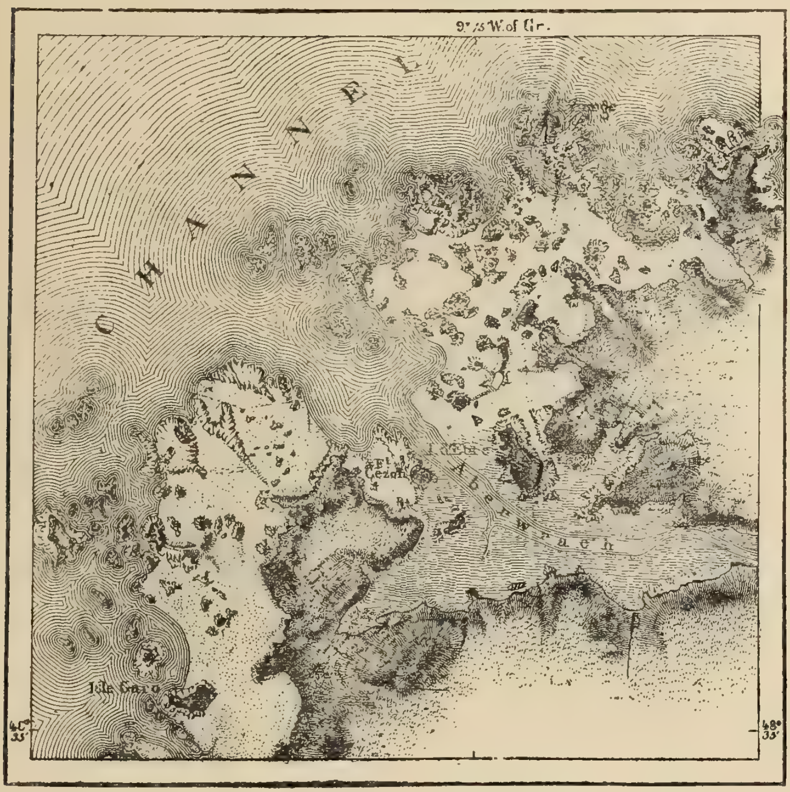
The Straits of Dover are being continually enlarged by the action of atmospheric influences, the waves, and the current which flows from the Channel into the North Sea. The patient researches of M. Thomé de Gamond, an engineer to whom we owe the fine project of the international tunnel between France and England, have proved that the cliff of Gris-Nez, the nearest point of the French coast to Great Britain, loses on an average more than 27 yards per century. If in former ages the progress of erosion was not more rapid, it would be about 60,000 years before the present epoch that the isthmus connecting England with the Continent was broken by the pressure of the waves. Nevertheless, it is impossible to indicate any date, since at this place the ground has sunk and risen at various intervals; ancient beaches four or five yards above the present level of the sea, as well as submerged forests, testify to these successive oscillations.

Along the coast of France, to the east of Cape Antifer, the pebbles resulting from the denudation of the cliffs are continually advancing towards the mouth of the Somme. Arrested at about 6 miles beyond these last flinty cliffs, by the promontory of Hourdel, so named from the dash (*heurt*, Fr.) of the waves, they are subsequently taken up by the current which runs towards the Strait. Triturated more and more, they travel from sandbank to sandbank, and after having passed the Strait, are deposited in beds of mud either on the surface of the innumerable banks of the North Sea, or on the coasts of Flanders, Holland, and eastern England. It is these deposits which are called by the expressive name of *gain de flot* ("winnings from the waves") in the neighbourhood of the Channel. The 10,000,000 of cubic yards of fragments taken annually from the cliffs of Sussex and Kent, as well as from those of Calvados and the Pays de Caux, are carried back to the coasts of the northern countries, and it is at the expense of the shores of the Channel that the *polders* of Holland and the fens of Norfolk and Lincolnshire are formed. In consequence of this double work of erosion at one point and deposit on another, the shores situated to the north of the Straits present a perfect contrast with the coasts of the Channel. While the cliffs of France and England, on the borders of this

sea, are cut into concave bays, the beaches which stretch to the north of the Straits of Dover uniformly exhibit a convex arrangement. The waves give back in sand and mud what they have taken in rocks and boulders.

We must not think that it is the force alone of the breakers that demolishes the cliffs along the shore. The sea would be almost powerless against the hard rocks, if, on approaching the shore, it was not charged with all kinds of débris—blocks and pebbles, sand and shells, projectiles which are hurled by every wave against the cliffs which oppose them. Using thus the stones that have fallen as so many battering-rams, the billows roll them over the strand to the foot of the cliffs, dash them against the projecting points, and finally break off masses and reduce them to sand. The sand itself, incessantly washed against the rocks, wears away the most

Fig. 58.—Map of Abervrach.



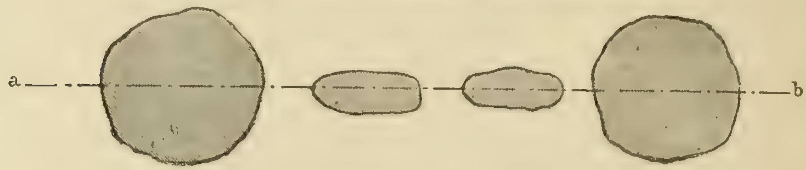
solid layers little by little, and thus continues the work of destruction commenced by the shingle; it is in great part the fragments of the promontory itself which serve to further its destruction. On all the rocky coasts of Scandinavia, Scotland, Ireland, and Brittany, the multitude of reefs that extend seawards for a great distance from the shore are nothing else than the ancient foundations of the continent, which have been gradually razed by denudation to a level with the water. From the top of any hill on the coasts of Paimpol, Morlaix, and Abervrach, we may thus distinguish at low tide what was the primitive form of the shore.

The deep and regular excavations known under the name of "giants' cauldrons," are the most curious of the geological feats accomplished by the scattered blocks. Every stone reposing on a ledge of the rock where the waves break, hollows out

during the course of ages a kind of well, the walls of which are polished and planed by the friction. Finally, these cavities, where the gradually rounded stone does not cease to oscillate, acquire a depth and width of several yards, and these are then, according to tradition, the cauldrons where the giants prepared their repasts in former time. Very remarkable excavations of this kind exist on the coasts of Scandinavia, where blocks of granite, rolled along by a furious sea, are retained by abrupt rocks in a great number of cavities.

Nor are the marine waters the only instruments in this work of constant wear

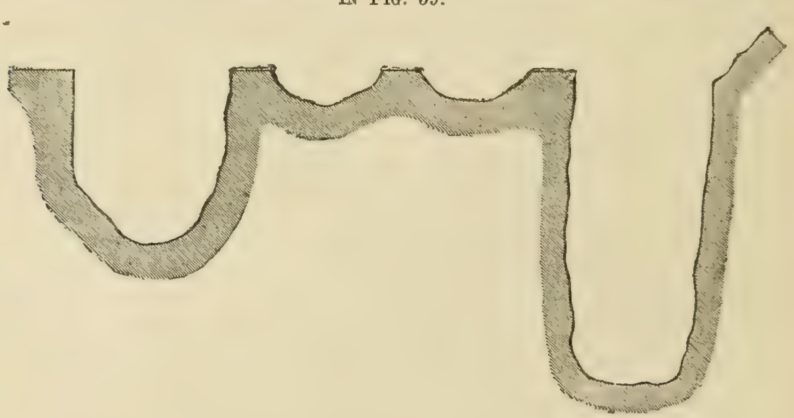
Fig. 59.—"Giants' Cauldrons" of Haelstolmen.



and tear, in which the loose shingle seems to serve as a sort of pestle for grinding the hard rocks into gigantic mortars. The same ravages are gradually brought about by the cataracts and the streams which, penetrating through the crevasses of the glaciers, excavate huge "cauldrons" in their rocky beds. In some places these excavations, aided perhaps by the planes of cleavage, are disposed in a horizontal direction.

A phenomenon not less interesting than the revolving of the stones in the giants' cauldrons, is the sudden appearance of columns of sea-water, which spring

Fig. 60.—Section of the "Giants' Cauldrons" of Haelstolmen, taken along the line *a b* in Fig. 59.



in jets through the fissures of the rock. When a large wave is swallowed up in one of the fissured caverns on the coast, its force is sometimes so great that the rock resounds as with the discharge of artillery. The mass of water drives the air before it, and not finding in the walls that surround and compress it a large enough space to develop itself, springs through the crevices of the vault. Most of these fissures, gradually sculptured anew by the waters which escape from them, at length assume the appearance of real wells, where each return of the wave is signalized by a sort of *geyser* of variable dimensions. There are some which spring several yards high, and can be seen at a great distance, like the jet of water by

which the whale betrays himself afar off; hence arises the name of blowers (*souffleurs*) given in many countries by sailors to these phenomena on the shore.

The pressure of the tide does not make itself less felt than the force of the waves in the interior of the fissured rocks of the coast. It does not, it is true, cause magnificent fountains to spring far above the sea, but it lowers the level of the water in all the wells near enough to the shore, even in those that are filled with fresh water. And this is what theory could have indicated beforehand: the mass of water that penetrates far into the crevices of the rock retains the waters which infiltrate from the interior; the latter, salt or fresh, remain in their reservoirs, and rise at the same time as the tide; then, when the ebb commences, they flow into the sea, and overflow again as soon as the pressure of the rising water ceases. Where the rocks of the coast are much fissured, which is almost everywhere the case with cliffs composed of calcareous strata, there exist these "tidal" wells, which rise and fall alternately with the tide. We may specially cite those of Finland, near Wasa, those in the environs of Royan, on the right bank of the Gironde, and, above all, those of the Bahama Islands. In many of these islands, all the wells, without exception, are regulated by the flow of the sea, and the time when water may be drawn from them is well known to the inhabitants. The saline fluid often

Fig. 61.—Tidal Wells.

penetrates to the bottom of the wells, whilst the sweet water continues to float on the surface. A remarkable instance is mentioned by Emerson Tennant on "Rama's Bridge," between the island of Ceylon and the Indian peninsula.

There are even certain coasts opening so deeply into large hollows, on the side towards the sea, that the waves penetrate to a great distance into the interior of the continent. A curious example of this is seen in that part of Louisiana known under the name of the Attakapas. There the grassy coastlands, protected against the tempests of the Gulf of Mexico by chains of sandbanks and long islands parallel to the shore, incessantly gain upon the ocean. But they are only solid on the surface, for their roots are bathed by the sea water, which advances far into a bay with invisible outlines. The fishermen do not fear to venture on these floating meadows, resembling fens in every respect, and it is by piercing the ground underneath their feet that they procure the fish hidden in these retreats.

Nevertheless, such floating shores can only exist on a small number of coasts, where the physical circumstances are quite exceptional; usually it is by grottoes and caverns hollowed out of the solid rock that the waters of the ocean penetrate far into the land. It is not to be doubted that there are below the level of the sea multitudes of these rocky galleries, but only those are known that are open to the strike of the waves, like the azure grotto of Capri. Lower down, the water closes the entrance to the lateral caverns, which will doubtless long remain unknown to us.

But if we cannot explore grottoes still filled by the sea, we can at least see on elevated coasts, like those of Scandinavia, immense caverns which the waves once freely traversed. One of the most imposing grottoes in the whole world is that which penetrates the splendid rock of Torghatten, rising like an enormous pyramid to more than 900 feet, on an island of northern Norway. This gallery, through which seamen see the light glimmering, is of an astonishing regularity. The thresholds of the immense portals, one of which has an arch of nearly 234 feet and the other of nearly 144 feet span, are found on each side to have the same elevation of 375 feet above the level of the sea. The ground, covered with fine sand, is almost level, and formed like the floor of a tunnel, where carriages might roll. The lateral walls present almost throughout a polished surface, as if they had been cut by the hand of man, and rise vertically to the spring of the arch; only towards the centre of the grotto the vault is less elevated than at the two extremities Seen through this gigantic telescope, 900 feet long, the promontories, islets, innumerable reefs, and the thousand white crests of the breakers, form a spectacle of incomparable beauty, especially when the sun illumines the whole landscape with its rays.

When the waves of the sea cannot enter into the caverns remote from the shore except by narrow channels, it often happens that a rivulet of salt water regularly flows towards the interior of the land, without ever returning to the ocean. This strange fact, which may seem at first sight a reversal of the laws of nature, may be observed on various points on the coast of calcareous countries, and especially on the coasts of Greece and the neighbouring islands.

Near Argostoli, a commercial town in the island of Cephalonia, four little torrents of sea-water, rolling on an average 55 gallons of water per second, penetrate into the fissures of the cliffs, flow rapidly among the blocks that are scattered over the rocky bed, and gradually disappear in the crevices of the soil. Two of these water-courses are sufficiently powerful to turn throughout the year the wheels of two mills constructed by an enterprising Englishman. Though the subterranean cavities of Argostoli are in constant communication with the sea, and the entrance to the canals is carefully freed from the seaweed that would obstruct the passage, or at least retard the current, the waters are not the same height in the grottoes as in the neighbouring gulf. This is because the calcareous rocks of Cephalonia, dried on the surface by the sea-breeze and the heat of the sun, are pierced and cracked throughout by innumerable crevices, which are so many flues aiding the circulation of the air, and the evaporization of the hidden moisture. We can compare the entire mass of the hills of Argostoli, with all their caverns, to an immense *Alcaraza,* the contents of which are gradually evaporated through the porous clay. In consequence of this constant loss of liquid, the level of the water is always lower in the caverns than in the sea, and to restore the equilibrium, the brooklets, which are fed by the waves, descend incessantly by all the fissures towards the subterranean reservoirs. It is probable that the constant evaporation of the salt water has resulted in the accumulation in the cavities of the island of enormous saline masses. Professor Ansted has calculated that the discharge of the two great marine streams of Argostoli would be sufficient to form each year a block of more than 1800 cubic yards of salt.

CHAPTER XIX.

UNDERMINING OF ROCKS.—VARIED ASPECT OF CLIFFS.—PLATFORMS AT THEIR BASES.—RESISTANCE OF THE COASTS.—BREAKWATERS FORMED BY THE DETRITUS.—HELIGOLAND.—DESTRUCTION OF LOW SHORES.

ALL the rocky promontories exposed to the violence of storms, or simply washed by a current, are undermined at their base. The wearing away is accomplished in a more or less rapid manner, according to the progress of the waves, the distribution and inclination of the strata, the hardness of the rocks, and their chemical composition. The method of destruction depends at the same time on various hydrological and geological conditions. Strange as this assertion may appear, the water of the sea can even in certain cases destroy the rocks on its borders by combustion. Thus, the cliffs of Ballybunion, on the western coast of Ireland, long presented the appearance of a rampart of smoking lava. These rocks, which the waves of the Atlantic have pierced with grottoes, and sculptured in massive and fantastic forms, having one day fallen down very extensively, the alum and iron pyrites, which are contained in considerable proportion in the rocks, were exposed to the action of the atmosphere and the sea-water. A rapid oxidation took place, and produced a heat sufficiently intense to set the whole cliff on fire. For weeks the rocks were burning like a vast coal-fire, and masses of vapour and smoke rose like clouds above the high wall besieged by the surf. Scattered around the space where the fire had prevailed, was to be seen a heap of melted scoriæ, and clay transformed into brick by the violence of the fire.

Such is the diversity of destructive agents employed by nature, that, as we can easily understand, the aspect and form of the rocky coasts varies likewise in a remarkable manner. Thus the cliffs of England and Normandy, which are composed of somewhat friable rocks, fall when their lower strata are eaten away, and their sides being occasionally interrupted by "valleuses" (narrow openings where temporary or permanent brooks flow), they resemble enormous walls from 150 to 300 feet high. In the islands of the Baltic Sea, the chalky rocks, less exposed to the fury of the tempests than those of western Europe, are also less abrupt, and forests of beech-trees descend like sheets of verdure over the ruins of the cliffs. Elsewhere, especially on the coasts of Liguria, the promontories, formed of limestone rocks harder than chalk, do not fall in when their lower strata are carried away by the sea, and the waves, incessantly excavating the bases of these rocks, may carve them into colonnades, arched gateways, winding galleries, and vast grottoes, where the trembling water lights up the vaults with its azure hues. Other cliffs, of which the promontory of Socoa, near St. Jean-de-Luz, may be

considered as a type, are composed of slate rocks, variously inclined towards the sea. Worn away by the waves, some of the layers of schist are detached, others bend and part from each other, like the pages of an open book, allowing the water to glide in long foaming sheets into the very heart of the cliff, to spring up again from it in immense spouts. Finally, on other coasts, the rocks cut by vertical fractures are gradually isolated from one another, and separated into distinct groups by the action of the waters. Surrounded by a roaring sea, they rise on their rocky bases like towers, monstrous obelisks, gigantic arcades, or crumbling bridges. Such are the innumerable rocks which tower above the waves in the archipelago of the Orkney and Shetland Islands. Black, slender, and enveloped with spray as with smoke, these wrecks of ancient cliffs justify the name of "chimney-rock" which the English have given to many of them. On the northern coasts of Norway, not far from the polar circle, a rock rises in the midst of the waves, more than 900 feet high, which resembles a giant cavalier; hence its name of Hestmanden.

We see that the rocks which the sea-wave has eaten away are very various in form. Still we may say, as a general rule, that the inequalities of cliffs are in direct proportion to the hardness of the strata. The grooves that the waves slowly hollow out in the surface of the rock, the cavities that they scoop out in it,

Fig. 62.—Cliff on the Mediterranean.

the arcades and grottoes which they excavate, are the deeper the harder the stone is, for the beds of less solid formation fall in as soon as the lower layers are eroded. That part of the cliff which is only wetted by the foam and the mist of minute drops, is less cut up than the base, and the grooves are less numerous there; but no vegetation as yet appears. Higher up a few lichens give a tint of greenish gray to the stone. Finally, those bushes which delight in breathing the salt air of the sea make their appearance in the angles and on the cornices of the rocks. It is at 100 or 120 feet high that this vegetation begins to show itself on the cliffs at the border of the Mediterranean.

Notwithstanding the astonishing variety of aspect presented by cliffs composed of various substances, chalk, marble, granite, or porphyry, we can still observe one trait of singular appearance in the form of the rocks, which are covered by the waters of the sea at the foot of the abrupt walls. This feature consists in the existence of one or two platforms of varying dimensions, situated at the base of the escarpments. On the coasts of the Mediterranean and other seas with a very slight tide, where the level of the waters hardly varies excepting under the influence of the winds and storms, there is but a single one of these platforms, while on the shores of the ocean, where the tides attain a height of at least several yards, two steps, one above the other, extend below the wall of the cliffs. When

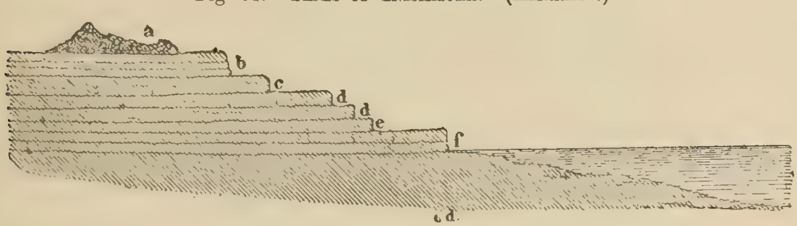
the rock is very hard the platforms present but a few yards in width, and perhaps may then be compared to a narrow cornice, suspended at mid-way between two abrupt walls—that of the cliff, and that which plunges into the abyss of the water. On the other hand, when the rocks are easily cut, the terrace of one or several stages over which the waves roll has sometimes many hundreds of yards in width. At Inishmore, on the western coast of Ireland, the cliff presents a succession of regular steps like those of a staircase cut out for giants. The highest step, all

Fig. 63.—Ocean Cliff.

encumbered with blocks, is that attained by the waves during a tempest; lower down are those bathed by the spring-tides, and then that where the ordinary tides are arrested. Still lower are the intermediary terraces, and the last two steps of the staircase are those where the water breaks during ordinary ebb, and at the low tides of the equinoxes.

It will be easily understood that these submarine ledges were formerly embedded in the thickness of the rock; they have resisted the assault of the waves, while the

Fig 64.—Tides of Inishmore. (Kinahan.)



a. Deposit of tempests. *b.* Terrace of equinoctial tides. *c.* Terrace of ordinary high tides. *dd.* Intermediary terraces. *e.* Terrace of ordinary low tides. *f.* Low equinoctial tides.

higher strata, sapped at their base more or less slowly, have fallen into the water. As the force of the waves is felt much less in the mass of waters than on the surface of the sea, the rock only allows itself to be cut into at the place where the breakers dash. But its submerged slopes remain relatively intact, and maintain more or less exactly the ancient outline of the coast. This is the reason why there exist on the shores of the Atlantic, and other seas, the level of which oscillates alternately with the ebb and flow, two platforms, one above the other, which correspond, the one with the level of low water, the other with that of high water. At the time of flow, the waves, urged by the tides, and more often too by the wind

which accompanies the tide, dash impetuously against the rocky walls, and push on vigorously their labour of destruction. During the period of the ebb, on the contrary, the water which breaks on the shore is retained by the current of low water, and is as though attracted towards the open sea; neither does it attack the cliff with as much energy as the rising tide. The difference which exists between the force of the waves of the flow and those of the ebb can be measured by the respective extent of the intermediary platforms.

If the waves march constantly to the assault of the shore, to transform into cliffs the heights of the coast, the latter, on their side, are not satisfied with merely resisting by their mass, and by the greater or less hardness of their strata, but many of them besides take care, one might say, to protect their threatened base against the waves. A thick vegetation of seaweed, like floating hair, drapes the cornices, breaks the force of the surf, and changes into torrents of eddying foam the enormous rollers which rush to attack the rocks with great speed. Besides, all that portion of the rocks comprised between the levels of high and low water is covered with balani and other shells, numerous enough to give the stone the appearance at certain hours of a swarming mass, and to form it afterwards into an immense immovable carapace.

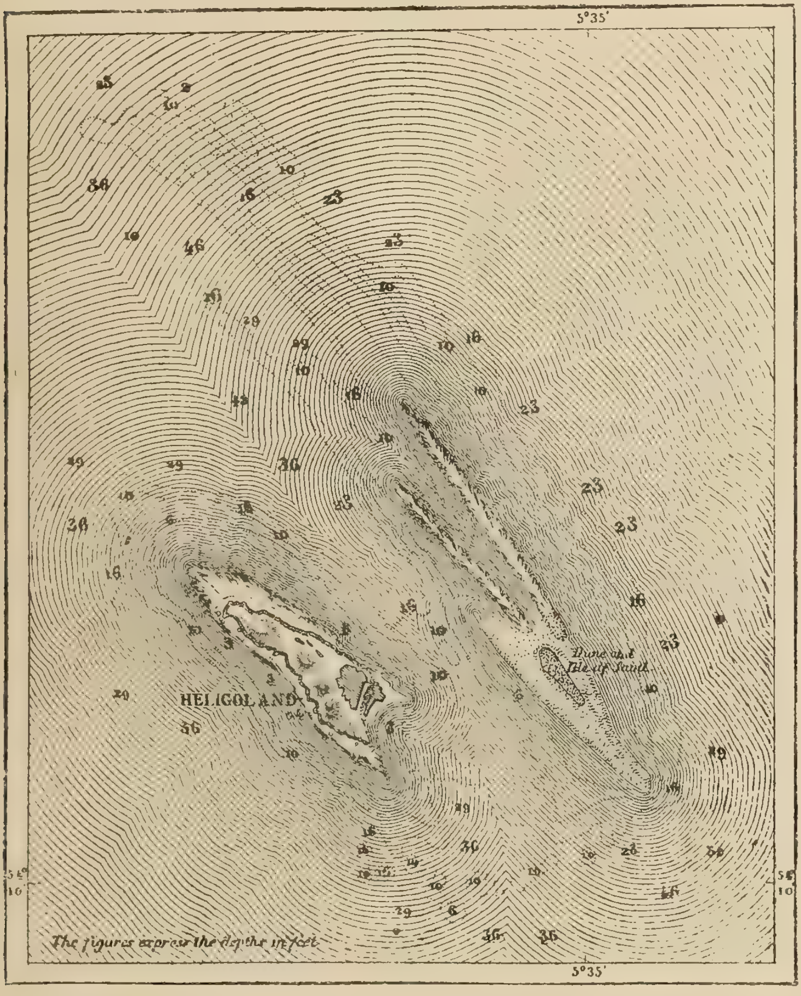
The coasts thus protected are precisely those which, by the solidity of their rocks would best resist the attacks of the sea. As to the cliffs composed throughout their thickness, or only at their base, of less resisting materials, they give way too often for the molluscs and seaweed to venture in great numbers on that part of the rock which the waves have just assailed. Great blocks detach themselves from the upper strata, and fall on the beach. Afterwards, under the action of the waves, they break into smaller pieces, then into pebbles which the surge rolls and chafes incessantly. Under these fragments, constantly moved by the waves, no germ of animal or plant can develop itself, no living organism brought from the open sea can exist there. A desert is made even in the waters which dash against the roaring mass.

When this is the case, it is the crumbling masses and the pebbles of the strand which themselves serve as bulwarks of defence to protect the wall of the cliffs from fresh damage. Supported in a slope on the lower part of the rock, or else scattered in the waves and transformed into shelves, the fallen blocks break the force of the waves and retard the progress of erosion. It is thus that on the coasts of the Mediterranean, near Vintimillia, the lower strata of the cliffs are composed of a sandy clay, which the rain alone suffices to wash away, and this gives rise to a talus of masses of solid conglomerate detached from the upper layers, which thus protect the cliffs from the fury of the waves. In the same way, on the sterile shores of Brittany, the blocks of granite, cracked in all directions, and converted into shingle which the sea carries away and returns again, maintain intact during centuries the walls of rocks of which they formerly made a part.

The cliffs of Normandy, composed of materials much less hard than those of the promontories of Brittany, are also more easily worn away; still we must attribute their rapid erosion principally to the coastal current which carries away the shingle accumulated at the base of the rocks. The talus of fallen blocks constitutes at first a perfectly sufficient defence against the fury of the waves; but little by little the chalky part of the rock is dissolved and deposited here and there on the mudbanks, while the masses of flint disengaged from the substance of the stone cease to present a sufficient resistance to the waves, and are carried away into the neighbouring bays in immense processions parallel to the shore. On the south coast of

England, the current of the coast is much less energetic, and the talus can in consequence long resist the attacks of the sea. A few years ago the waters undermined with a threatening rapidity the base of the cliff which rises not far from Dover, on the western side, and which the English have consecrated to Shakspeare, in remembrance of the beautiful description which he has given of it in *King Lear*. To preserve this historical promontory, the houses that it supports, and the railroad which runs through it in a tunnel, they formed the plan of blowing down the upper

Fig. 65.—Heligoland.



part. In the presence of an immense crowd, assembled to see this new spectacle, they fired hundreds of pounds of powder buried in a mine, and enormous masses of rock fell with a crash from the top of the hill; and now the force of the waves is broken on their talus. Mr. Beete Jukes thinks that during eighteen centuries this cliff and the neighbouring rocks have been worn away by nearly a mile.

In the North Sea there is an island which by a singular misapprehension was believed to have been consecrated to Freya, the goddess of love and liberty, and whose ancient name of Halligland (land with the inundated banks) has been trans-

formed for foreigners into that of Heligoland (holy land). The island, composed entirely of mottled stone, formerly surrounded by cretaceous beds, presents to the sea all around a cliff about 200 feet high, worn away at the base by the waves. By employing the heroic means which the English engineers have applied to the defence of Shakespeare's Cliff, and which the garrison of Heligoland had also inaugurated in the year 1808, by bombarding a crumbling cliff, the inhabitants might surround their island with a great circular breakwater. But this dike would not last long, for the strata of mottled stone do not contain those beds of pebbles which serve to form shingle for a beach. All the blocks would soon be dissolved by the waves, and, not a single fragment remaining to protect the lower strata of the cliff against the destructive action of the waves, the work of erosion would freely resume its course. Devoted to certain destruction, the island is gradually melting in the waters, like an immense crystal of salt.

The learned do not all give the same degree of confidence to the documents relative to the ancient extent of Heligoland. Some, such as Wiebel, regard those testimonies of the past as if destitute of sufficient authenticity, and think that the lessening of the island is accomplished very slowly. Others, on the contrary, placing more faith in the affirmations of the chroniclers, believe that in the space of five centuries the island has diminished by at least three-quarters. However this may be, it is certain that the partially inundated lands, to which the island owes its name, have long since ceased to exist. It is equally certain that towards the end of the seventeenth century, an isthmus still united Heligoland to another islet, the cliffs of which rose to about 100 feet in height, like the principal island; two excellent ports, which gave the island a great strategical importance, opened to the north and south between the two rocky masses and their submarine extensions. The eastern island has now disappeared, and its cliffs are replaced by a few dunes and sandbanks, uncovered at low water; the ports no longer exist, and ships of war of the largest size can sail freely where the isthmus still existed less than a century and a half ago. Who would now recognise in this rock of Heligoland, hardly 1½ mile long, and about 2000 feet broad, the land of which Adam of Bremen speaks in 1072, and which was then "very fertile, rich in corals, in animals, and birds," and which extended, says Karl Müller, "over a space of 900 square kilomètres." In the present day, a few rows of potatoes and a few meagre pastures are the only remains that testify to the ancient fertility of Heligoland.

If the sea thus destroys countries bordered all round with rocky promontories, it respects still less the low strands, which in consequence of some modifications in the geography of the coasts, or in the relief of the submarine banks, are disposed across the currents. In the very front of Heligoland, the shores of Hanover, Friesland, and Holland, which formerly seemed to sink gradually, offer the most striking example of this destructive power of the sea. During sixteen hundred years—that is to say, ever since written history commenced in these countries—the life of the inhabitants of the shores has been nothing but an incessant strife against the encroachment of the waters. During this period the great irruptions of the sea may be counted by hundreds, and among these there are some which, according to the chronicles, must have drowned whole populations of fifty and a hundred thousand souls. During the course of the third century, tradition tells us that the island of Walcheren was separated from the continent; in 860 the Rhine rose, inundating the country, the palace of Caligula (*arx britannica*) remaining in the midst of the waves. Towards the middle of the twelfth century the sea made a new irruption, and the Lake Flevo was changed into a gulf, which was still more

DEPTHS OF THE ZUIDER-ZEE

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enlarged in 1225, forming the Zuyder Zee, that vast labyrinth of sandbanks which, from a geological point of view, is still a dependency of the continent, and is separated by a long row of islands and dunes from the domain of the ocean. In the first years of the thirteenth century the gulf of Jahde was opened at the expense of the land, and never ceased to enlarge itself during two hundred years. In 1230 the terrible inundation of Friesland took place, which is said to have cost the lives of a hundred thousand men. The following year the lakes of Haarlem overflowed the ground, then gradually increasing, united with each other to expand into an inland sea towards the middle of the seventeenth century. In 1277 the gulf of the Dollart, which is nearly 22 miles long and 7 miles wide, began to be hollowed out at the expense of many fertile and populous tracts, and transformed Friesland into a peninsula. It was only in 1537 that they could arrest the invasions of the sea, which had devoured the town of Torum and fifty villages. Ten years after the first invasion of the waters in the Dollart, an overflowing of the Zuyder Zee drowned 80,000 persons, and changed the configuration of the Dutch coast-line. In 1421, seventy-two villages were submerged at once, and the sea on retiring left only an archipelago of marshy islands and islets, covered with reeds and banks of mud, in the place of fields and groups of habitations: this is the country known

Fig. 66 —Isle of Borkum in 1738.

under the name of Biesbosch (forest of reeds). Since this epoch many other hardly less terrible catastrophes have taken place on the coasts of Holland, Friesland, Schleswig, and Jutland.

Of the row of twenty-three islands which extended along the shore fifteen centuries ago, only sixteen fragments remain, and many are nothing else than simple ridges of sand. The Island of Borkum, as is shown by maps with less than a century's interval, has been singularly lessened; the Island of Wangerooge, the wreck of the antique country of Wangerland, which was once united to the continent and extended far into the sea, was in 1840 still a flourishing and populous island, and during the summer the bathers visited it in crowds. Now it is a strand of mud almost entirely abandoned. The Island of Nordstrand has diminished by eleven-twelfths since the commencement of the seventeenth century, and of the twenty-four islets which surrounded it 300 years ago, there only remain eleven; the lead, when thrown out at the spot which was formerly in the centre of the island, indicates a depth of 7 fathoms. The Island of Sylt, and other lands of the coast of Schleswig, have been also much worn away, and it is known that in the years 1624, 1720, 1760, and 1825 the sea opened a way quite across the peninsula of Jutland by hollowing out the Strait of Limfjord. The channels are displaced with every storm, and

according to the liquid volume to which they give access, the saline property of the Limfjord becomes continually modified.

The remarkable peninsula of Cape Cod, which projects far seawards south of Massachusetts in the United States, is one of those districts which, on the evidence of Agassiz and other distinguished geologists of New England, appear to have undergone the greatest changes during the last few centuries. At present the sandy beach exposed to the Atlantic surf develops an extremely regular curve,

Fig. 67.—Isle of Borkum in 1825.

analogous to that of the sharp edge of a skate. But at the beginning of the seventeenth century the symmetrical form of the coast-line was broken by a large island known by the name of Nawset, and by a long promontory at right angles with the shore. Owing to the disappearance of these tracts the total extent of the beach has been reduced by one-half or even two-thirds. This was probably the coast to which, about the year 1000, the Norse navigator Leif gave the name of "Wonderstrand."

CHAPTER XX.

NORMAL FORM OF SHORES.—CURVES OF "GREATEST STABILITY."—FORMATION OF NEW SHORES.—COAST RIDGES AND SANDBANKS.—INLAND BAYS.

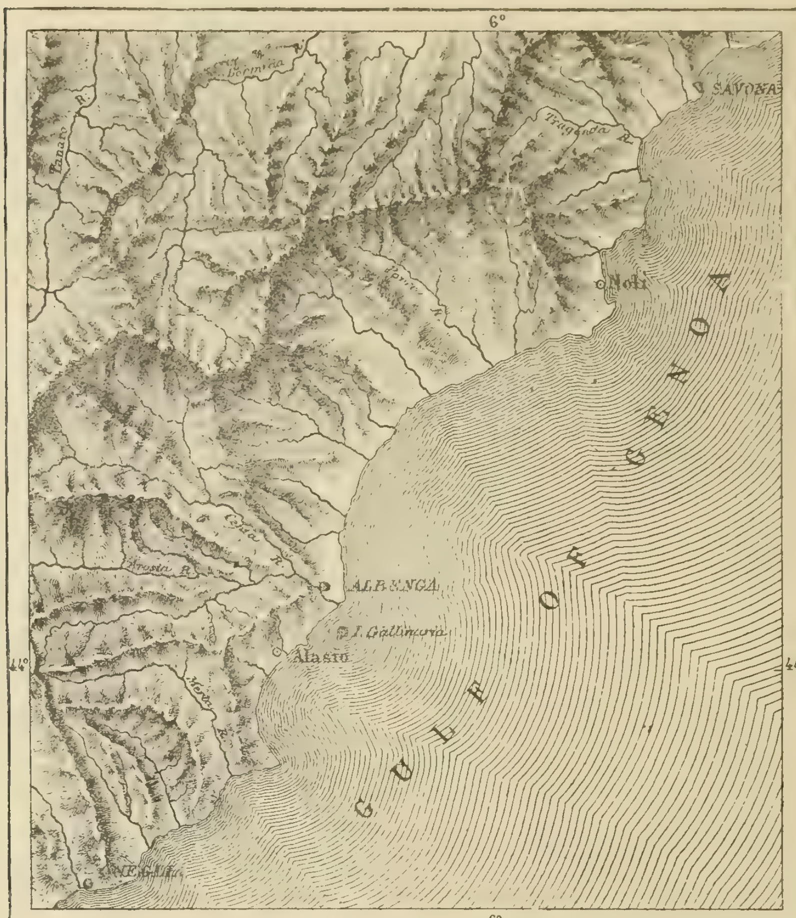
THE shores most violently attacked by the sea are, generally, those which present the most indentations and promontories. The waves break most of all against the advanced capes that jut out farthest into the domain of the waters; but in proportion as the points retreat before the tide which wears them away, the destructive power of the waves diminishes; its force will even in time be reduced to nothing, when the base of the cliffs is sufficiently eroded and describes no more than a slight curve in front of the coast. In fact, the outline of the coast which offers the greatest resistance to the assaults of the sea is not a straight line, as one might suppose, but a series of regular and rhythmical curves. The waves do not cease to labour at remodelling the shore as long as the latter does not present a succession of creeks gently curved from promontory to promontory. Each one of these rounded bays reproduces in large the form of the wave which breaks on it, drawing on the sand of the beach a long elliptical curve of foam-flakes.

The coasts of mountainous countries, to which the sea has already given the desired contours, unite an extreme grace with an admirable majesty. Such are the coasts of Provence, of Liguria, of Greece, of the greater part of the Iberian and Italian peninsulas. There every promontory, the remains of an ancient chain of hills razed by the waves, lifts its terminal point in a high cliff; each valley which descends towards the sea terminates in a beach of fine sand, with a perfectly regular curve. Abrupt rocks and gently sloping beaches alternate thus in a harmonious manner, while the various geological formations, the greater or less width of the valleys, the towns scattered on the heights or on the low shores, the curvatures of the coast, and the incessantly changing aspects of the water, introduce variety into the whole landscape.

Sandy shores, as well as rocky coasts, have a normal profile composed of a series of bays and points. But these points, the relief of which is modified by every wave, are generally more rounded in their extremity than the promontories of rock. The monotonous coast of the Landes, which extends over a length of nearly 140 miles, from the mouth of the Gironde to that of the Adour, may be taken as a type of the shores which the waves of the sea model at their will. On these coasts the uniformity of the landscape is complete. The traveller in vain hastens forward; he might believe he had hardly changed his place, so immutable does the aspect of the scenery remain; always the same dunes, the same shells scattered

on the sand, the same birds assembled by thousands on the edge of the lagunes, the same lines of waves which pursue one another, and break with great noise in a sheet of foam. In the whole field of view the only remarkable objects are the spars of shipwrecked vessels that can be seen from afar on the white sand. However, the shores which present the most regular series of convex and concave curves, which one might call the outline of the greatest stability, are exposed also to rapid erosions when the bulwark of defence which flanks them at either of their extremities yields to the pressure of the waves. Thus the shores of Medoc, which

Fig. 68.—Curves of the Coast between Oneglia and Savona.



are the continuations of the uniform coast of Saintonge, to the south of the bay of the Gironde, have incessantly retreated before the sea ever since the rocky promontory (of which the ledge of Cordouan is the sole remnant) disappeared under the united ravages of the river and the ocean.

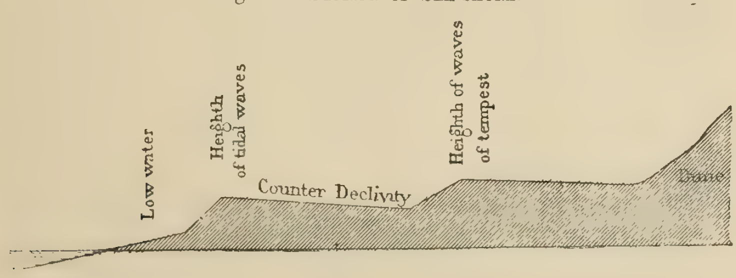
But if the sea demolishes on one side, it builds up on the other, and the destruction of the ancient shores is compensated for by the creation of new coasts. The clays and limestones torn from the promontories, the shingle of every kind which is alternately thrown up on the shore and swept back in the waves, the heaps of shells, the silicious and calcareous sands formed by the disintegration of all these

fragments, are the materials employed by the sea for the construction of its embankment and the silting up of its gulfs.

It is on each side of the cliffs or low points worn away by the waves that the work of reparation commences. Each wave accomplishes a double work, for in sapping the base of the promontory it loads itself with fragments which it deposits immediately on the neighbouring strand; by the same action it causes the point to retreat and the shore of the bay to gain. Thus, owing to two series of apparently contrary results, the razing of the points and the filling up of the bays, coasts more or less deeply indented gradually acquire the normal form with gracefully rounded curves. Whatever be the outline of the primitive coast, each inflection of the new shore rounds itself like the arc of a circle from promontory to promontory. In those places where the ancient coast was itself semi-circular, the sand or gravel cast up by the billows is deposited on the beach; but when the coasts are irregular and indented by deep creeks, the sea simply leaves them and constructs sand or shingle banks in front of them, which end by becoming the true shore.

The formation of such a breakwater may be explained in a very simple manner. The waves of the open sea, driven against the shore, first strike the two capes placed as guardians at the two extremities of the bay; here they break their force, and are thrown back against the tranquil waters of the bay. Thus arrested in

Fig. 69.—Section of Sea-shore.



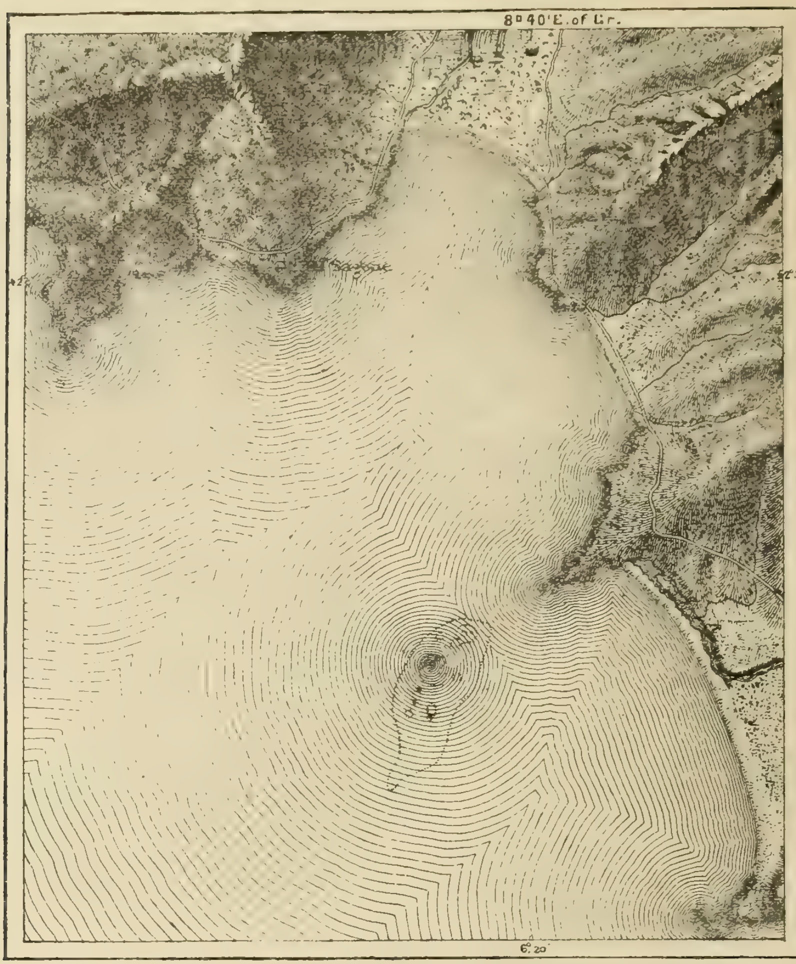
their speed, they deposit the earthy matters which they hold in suspension, and also the heavier fragments torn from the neighbouring promontories. At the entrance to the fjords of Scandinavia, of Tierra del Fuego, and all the other mountainous countries with deeply indented shores, the clear and deep water of the open sea only brings with it a relatively small quantity of *débris*, and can only form a submarine bank from point to point. But along the lower coasts where the tide drives before it masses of sand and clay, the ramparts of alluvium constructed by the waves emerge gradually from the bosom of the waters.

Under the alternate influence of the ebb and flow the sand and shingle are gradually deposited against the rocks of the capes, and thus they form at the entrance of the bay true jetties, the free extremities of which advance to meet each other. Being elongated unceasingly, the two segments end by uniting midway between the two capes, and thus form a large arc of a circle, the convexity of which is turned towards the ancient shore. The most furious assaults of the sea only serve to consolidate these banks by bringing other materials to them, and raising them above the level of the tides.

All these sea-banks present a geometrical regularity in their section; their form is, so to say, the visible expression of the laws which govern the undulation of the waves. Most often that part which fronts the sea is composed of several separate slopes which correspond to the different levels of low water, high tide, and

storms; but all these beaches present uniformly a graceful curve, modelled by the breakers. At the base of the embankment the slope is very slight, and simply continues the declivity from the bottom of the sea; but it rises suddenly at an angle that is sometimes not less than from 30 to 35 degrees. Immediately beyond this edge a counter-slope begins where the upper curve of every high wave spreads in a foaming sheet. Further on rises a second talus, which the stormy waves sometimes strike and consolidate The inclination of this second stage which looks towards the sea is very slight. From this side, the materials of the embankment,

Fig. 70.—Mouth of the Liamone.



sheltered from the force of the wind and from the violence of the waves, are gradually heaped up, and may even at length be covered by a bed of vegetable earth. Above this level dunes rise, or else we find the surface of the ancient bay transformed into a lagune. This outline of the shores is represented by the illustration on page 137, where the heights are strongly exaggerated.

Notwithstanding the looseness of the materials which compose them, the banks are more solid than the promontories of rocks against which they rest, and when the cliffs have been levelled by the waves, the banks of sand again extend from one ledge to the other. They can be displaced by the influence of the currents and

the winds, but they do not the less continue apparently immovable and more durable than the mountains. They do not, however, present a continuous development. When the inland bay is fed by one or several rivers, the mass of water which is discharged in this closed basin must necessarily break a passage to the sea, and pierce this ridge at the spot where it offers least resistance; that is to say, most often at one of its extremities. A remarkable example of this phenomenon is to be seen in Corsica at the mouth of the Liamone. In countries where the year comprises a dry period and a rainy season, most of the lagunes on the coast are alternately completely separated from the sea, and united with it by temporary

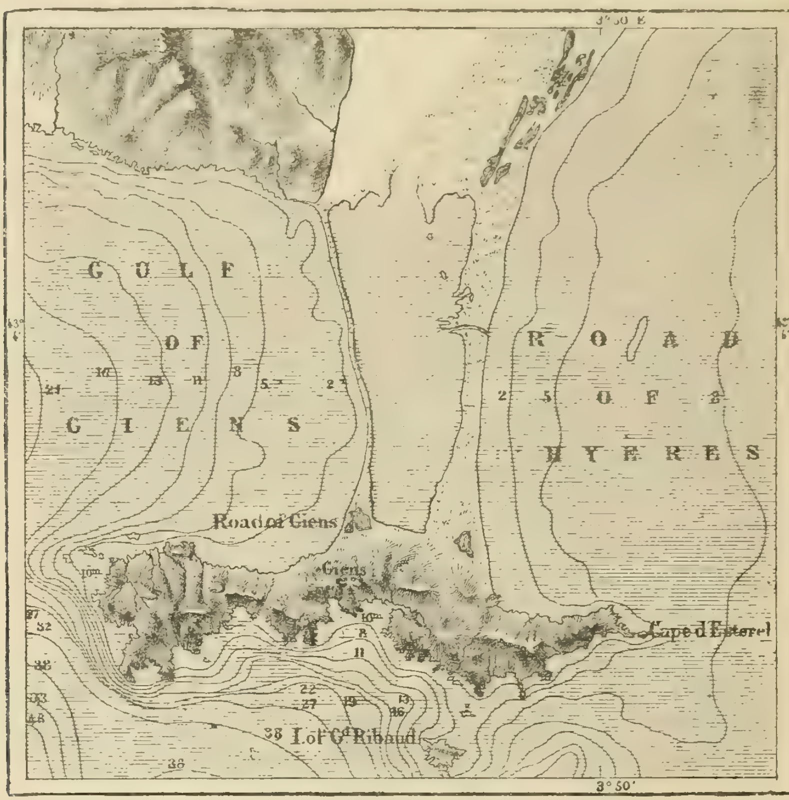
Fig. 71.—Mouth of the Bidassoa.

embouchures of inconsiderable depth. When the mass of rain waters has flowed away, the breaches in the broken bank are instantly restored by the waves. In the same manner on the shores of seas with strong tides, a number of rivers are alternately canals of almost stagnant water, which a bank of sand separates from the ocean, and vast estuaries up which flows a powerful tide from the open sea. Thus, the Bidassoa, separated from the gulf at low water by a most graceful curved sandbank, is at the time of high water an arm of the sea from 2 to 3 miles wide. Almost all the small watercourses which discharge themselves into the Atlantic are alternately rivers and marshes twice a day. Even the Orne itself,

whose large delta spreads like a fan beyond the coast-line, is lost in a shingle-bank at the time of low water.

If the permanent or periodical watercourses open for themselves a passage through the bank, these very rivers, on the other hand, serve to bring the inland shore and the sea shore gradually closer together by depositing their alluvium in the interior lagunes. The reeds and other plants which delight in the turbid waters contribute also to the transformation of the ancient bays into marshes and firm ground. Beds of vegetable detritus accumulated in the bays during a succession of years and centuries, rise in time above the ordinary level of the waters; and then come great trees which solidify the soil, and attach it definitively to the continent. In the tropical regions, it is the different species of baobab and

Fig. 72. – Peninsula of Giens.



mangroves that aid most in the formation of the new shores. Raised on the scaffolding of their high roots, like aërial buttresses one above another, they grow in the midst of the lagune. Hidden by the floating forest, the muddy liquid is soon filled with rubbish; the branches and uprooted trunks of the trees, being much heavier than the water, incessantly raise the bottom, and end by appearing on the surface. A new vegetation immediately takes possession of this yet undecided shore.

The same hydrological laws which determine the formation of banks between two capes are at work to bring about the same result between two islands, or an island and the mainland. On the coasts of Europe a great number of coast lands have thus lost their insular character, and are changed into peninsulas; the strait

has been gradually changed into an isthmus. The peninsula of Giens, between Hyères and Toulon, presents a remarkable example of this transformation. It is connected with the continent by two banks of fine sand, above 3 miles long, each developed in regular curves, which turn their concave faces towards the open sea. Between these two banks stretches the vast lagune of Pesquiers. At the sight of this inland sheet of water and these low shores, hardly elevated above the level of the Mediterranean, one cannot doubt that the mountainous peninsula of Giens was formerly an island like Porquerolles or Port-Cros, and that the two roads, now

Fig. 73.—Section across the Peninsula of Giens.

separated, of Hyères and Giens, were formerly one strait. The two uniting banks which joined the ancient island to the coast of Provence, have been raised by the waves in the same manner and on the same plan as the coast ridges of the continent. As to the differences of appearance, they can all be explained by local circumstances. Thus the bank which the isthmus of Giens turns towards the west is composed in reality of two unequal fragments, due to the existence of a submarine reef which breaks the force of the waves at a little distance from the strand.

Fig. 74.—Peninsula of Cape Sepet

The Depths are expressed in fathoms.

It is equally to local causes that we must attribute the inequality of thickness presented by the two ridges of the isthmus. Undoubtedly the eastern bank owes its greater solidity and height to the double action of the marine current that tends from east to west, and of the mistral which blows the opposite way in the direction from north-west to south-east; the two contrary forces have left as witness to their strife this rampart of sand and *débris*.

The peninsulas of Cape Sepet, near Toulon, of Quiberon, in Brittany, of Monte

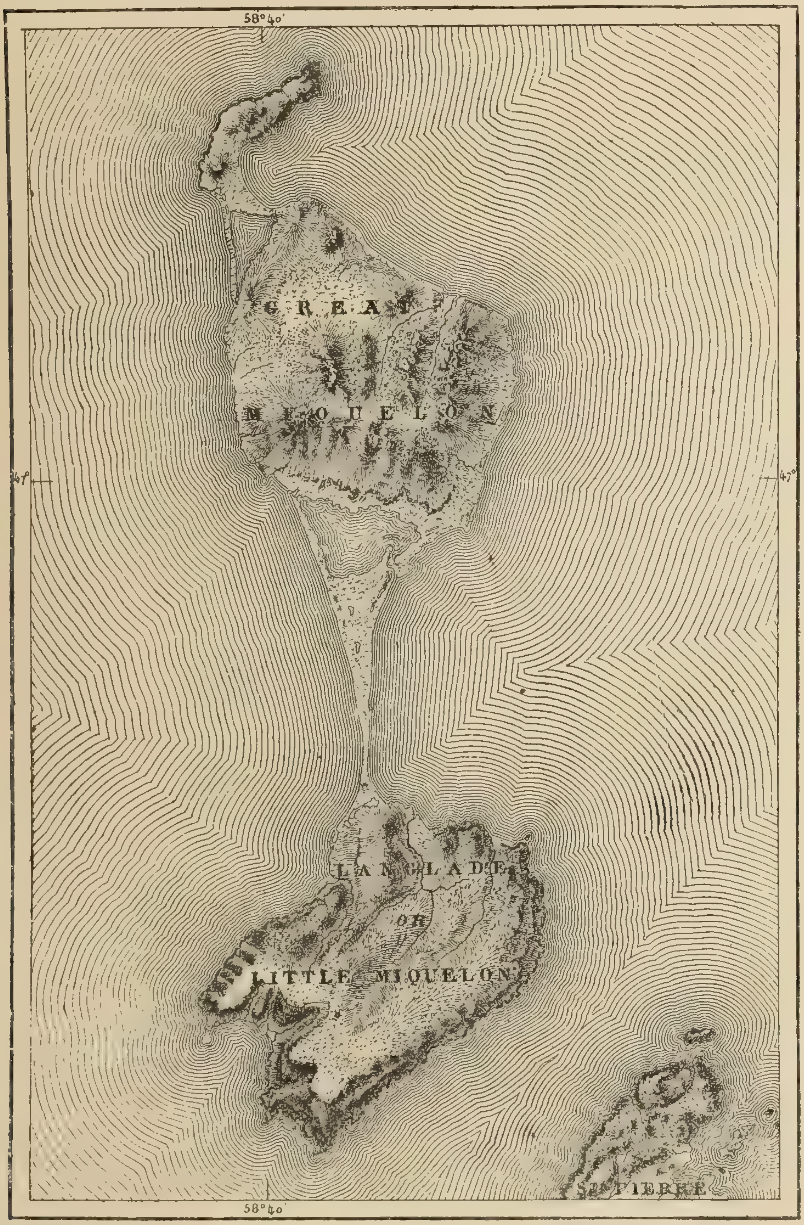
Argentaro, on the coasts of the Tyrrhenian Sea, and others less known, have been united to the continent by similar connecting causeways analogous to those of Giens. There, too, the two armies of waves which break in the midst of the strait have gradually erected between them a double wall of separation, consisting of banks of sand and shingle. There, too, the two semicircular jetties have drawn nearer together in their central convexity, and the two triangular spaces, which separated the respective extremities, have at first been occupied by lagunes. In our days, most of the ponds, gradually filled up by sand, have been transformed into marshes or covered by dunes; the two littoral ridges have been mingled in a single one. Thus, the narrow isthmus of Chesil Bank, which extends over a length of 16 miles, between the coast of England and the former island of Portland, is

Fig. 75.—Chesil Bank.

composed of a single bank of shingle. In the same manner, the two French islands of Miquelon, near Newfoundland, which were still separate from each other in 1783, have been united since 1829 by a rampart of sand, which the waves of two opposite gulfs have erected conjointly. Guadeloupe is likewise an example of this phenomenon of junction between two lands of distinct origin. The range of volcanic mountains which rise to the west is united to the low island of the east, and the two islands are now joined to each other by a marshy plain, where the waters of the small canal, called the Salt River, stagnate. In the two islands of Choa-Canzouni, bathed by the waters of the Indian Ocean, an analogous phenomenon is presented, but there the connecting bank between the two islands is reduced, so to speak, to a mathematical point.

M. Elie de Beaumont estimates the length of the coasts which owe their present configuration to banks of shingle and sand to about one-third of the total development of the continental shores. It is in these basins with slight tides that these ridges present the most considerable dimensions. In France, all the shores of the

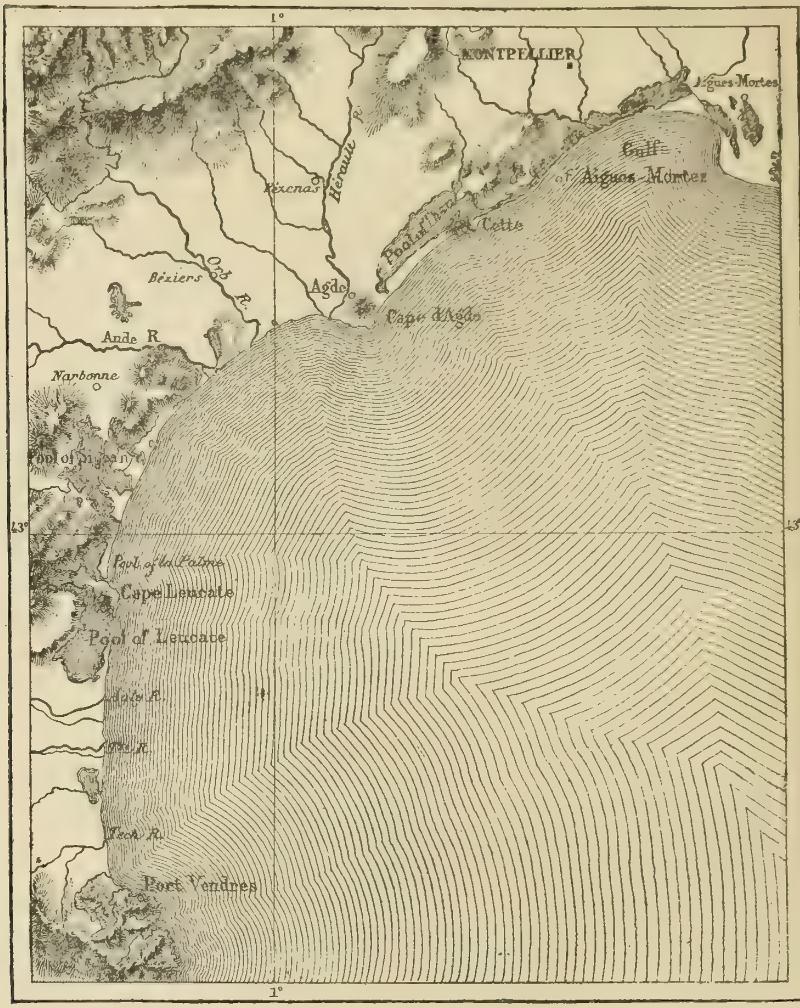
Fig. 76.—Miquelon Isles.



Gulf of Lyons, from Argelez-sur-Mer to the mouths of the Rhone, form a series of coast-ridges, only interrupted by the rocks of Leucate, of La Clape, Agde, and Cette, and developed in a vast semicircle nearly 125 miles long. The numerous ponds or *étangs* which it now separates from the Mediterranean, and which the

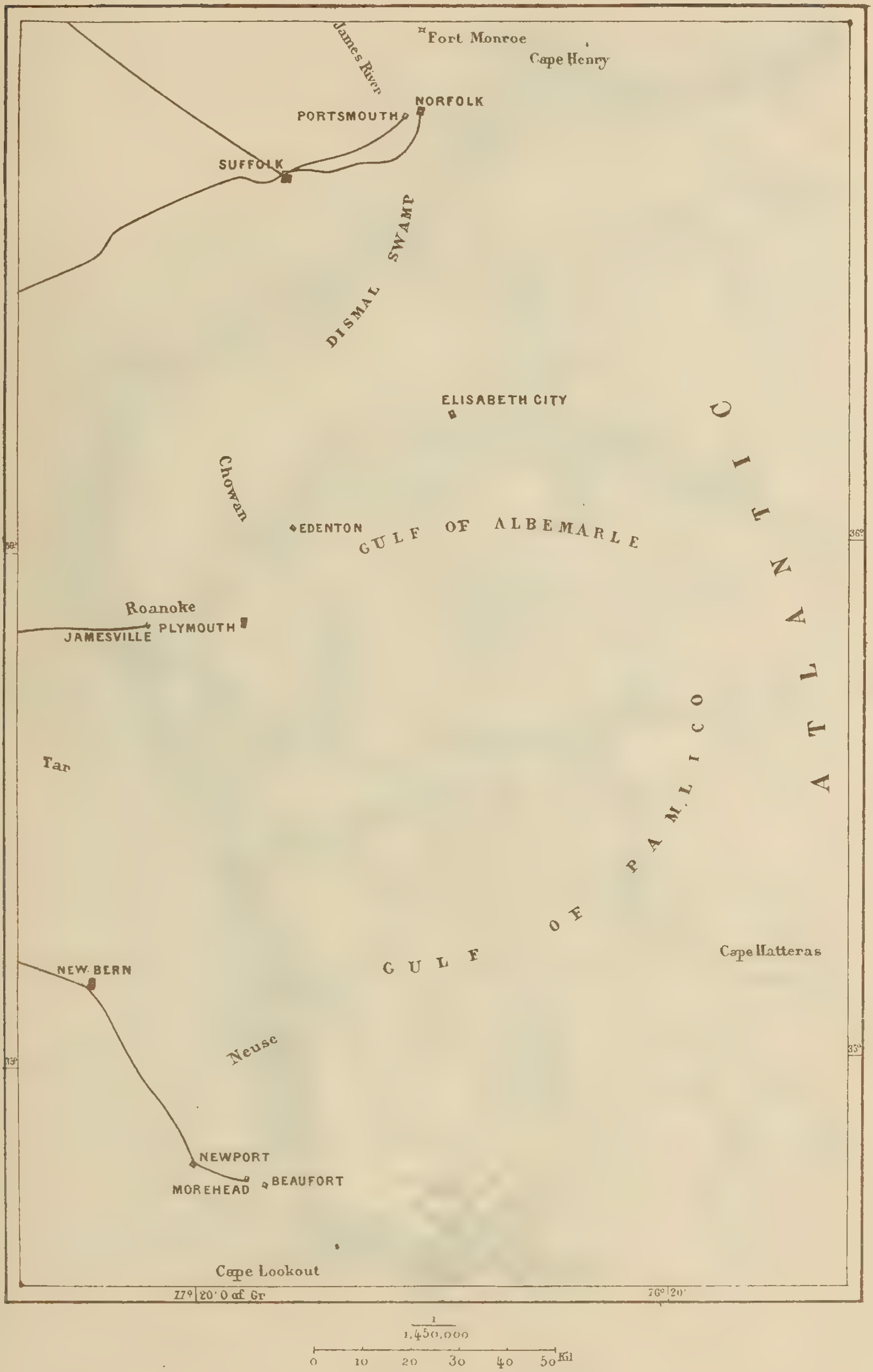
alluvium of the rivers, the marine sand, and invading agriculture are unceasingly transforming into solid earth, were doubtless so many bays along the base of the hills of Languedoc. Even since the historical epoch, these inland waters have notably diminished in extent, and vast gulfs, changed into marshes, to the great detriment of the public health, have poisoned the atmosphere with their miasma. That which contributed most actively to the diminution of the surface of the pools were the *graus*, or passages by which the water of the sea brought in heaps of

Fig. 77.—Coast-ridges between Port-Vendres and Aigues-Mortes.



sand during tempests. These openings, some temporary, and others permanent, but enlarging and diminishing by turns, and changing place, now in one direction and now in another, do not cease to modify the condition of the *étangs* and countries on the coast. Here they allow masses of water to break through, which submerge the shores and excavate the soil, and elsewhere they are obstructed, and spread banks of fetid mud as far as the eye can see before the villages of the coast. In order to prevent for the future the transformation of the *étangs* into mud and marshes, M. Régy has proposed to replace the old tortuous *graus* by channels for

SAND BANKS OF NORTH CAROLINA.



drainage, which, during the fine weather, allow the lacustrine waters and those of the sea to communicate freely, but the sluices of which would be closed during storms.

The *lidi* of Comacchio, as well as those of Venice, and of the ancient city of Aquileia, restrict the basin of the Adriatic, which formerly penetrated much farther into the lands to the west and north-east. On the southern coasts of Brazil and the Guinea coast, the littoral ridges thus cut off considerable tracts from the ocean; but nowhere are these *levées* of sand seen more numerously and better developed than around the Gulf of Mexico, and on the eastern coasts of the United States. We may say that over a length of about 2500 miles the outline of the American continent is formed of a double coast, the one bathed by the sea and the other by the interior lagunes. In front of the ancient coast, with its irregular indentations, the new shore describes its graceful curves from promontory to promontory, and not even allowing itself to be arrested by the mouths of the rivers, stretches across the outlets in dangerous bars.

Fig. 78.—Lagunes and Lidi of Venice.

Thus the indented coasts of North Carolina, and the ramified gulfs which cut into these peninsulas, and are prolonged even into the interior of the land, in the form of marshes, are masked on the side next the sea by a natural bank nearly 220 miles long, against which the most fearful waves of the northern Atlantic break. These banks so gracefully curved are not constructed by the sea alone. They are due also to the pressure of the fresh waters brought from the Alleghanies by the Neuse, the Tar, the Roanoke, and other rivers; the direction of the breakwaters indicates precisely the line of equilibrium between the marine and fluvial waters. Within the outer coast-line it has been possible, without any considerable artificial means, to put the whole series of interior lagunes in communication with one another, and thus to allow ships to make long sea-voyages completely sheltered from storms. Even the *marigots* of Guinea, which spread parallel to the shore, have at all times served to facilitate traffic between the peoples of the coast; but it is said that these marshy canals are gradually being filled up, either by the activity of the vegetation, or because of the sand which the wind of the desert transports thither.

Much less extensive than the banks of the Gulf of Mexico and of Carolina, those of the eastern Baltic are not less curious by the geometrical regularity of their forms, and, besides, they have been the object of long and serious study. Three great rivers, the Oder, the Vistula, and the Niemen, discharge themselves each into a vast lagune or *Haff* (*hafen*, port), which a narrow tongue of land, called there a *Nehrung*, separates from the open sea. The *haff* of the Oder, the entrance to which is guarded by the town of Swinemünde, is already in great part filled up by mud. The *Curisches Haff*, or haff of Courland, is much freer from alluvium, and the Nehrung which defends it is a narrow sandbank about 68 miles in length. The central *haff*, known under the name of the *Frisches Haff*, is protected by a bank similar to that of Courland, but still more regular. All the western part of the estuary has already been filled up by the alluvium of the Vistula, the waters

Fig. 79.—Coasts of Dantzig and Pillau.

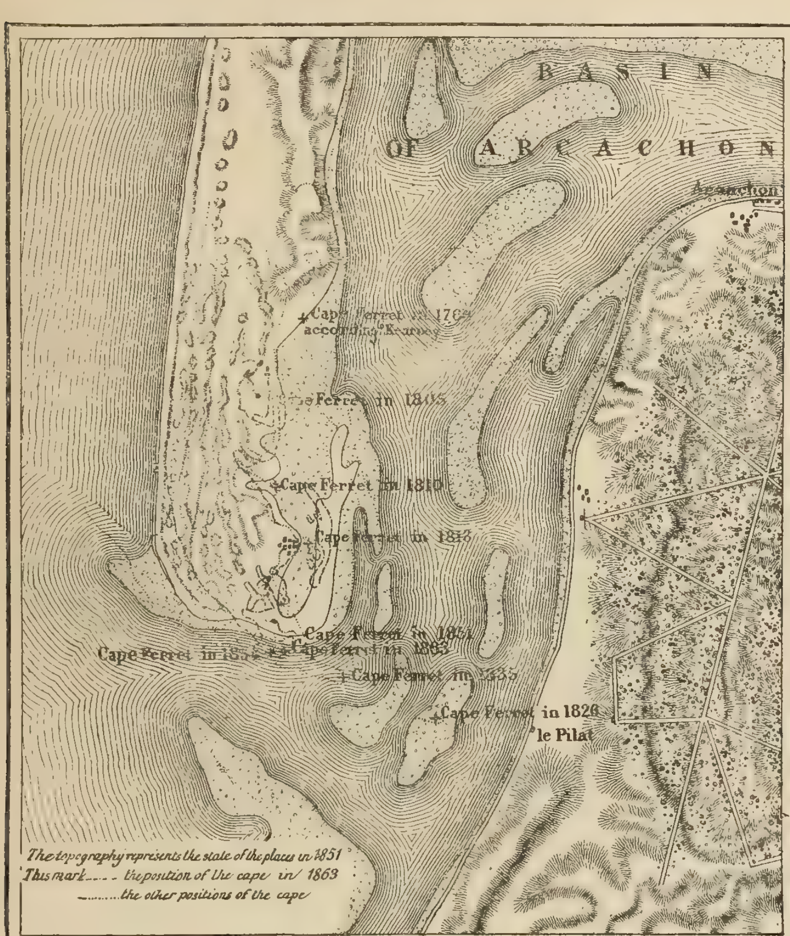
of which have opened a way through the bank. This embouchure has often changed its place. Till the fourteenth century it was to the north of the present passage, near Lochstädt (town of the gap or *grau*). Later, it opened at Rosenberg, nearly in the middle of the dike. To preserve their commercial monopoly, the merchants of Dantzig filled this opening up by sinking five ships there; but another passage was formed almost immediately at a little distance towards the north, near the castle of Balga. More greedy than wise, the Dantzigers again attempted to arrest the waters of the Vistula, and closed the passage of Balga. It was then that the *Nehrung* was broken before Pillau. Since this period the passage has not been sensibly displaced, and Pillau has always remained the port of the *Frisches Haff*.

To the north of Dantzig a curious bank, 20 miles long, unites the mainland to the picturesque island of Hela (the holy). Doubtless the ancient inhabitants of

the country experienced a sentiment of religious terror at the sight of the rude waves which assail this wooded hill, united to the continent by this narrow dike of sand stretching far away into the dim distance.

It is to the same order of phenomena that we must refer the gradual prolongation of tongues of land, which, bathed on either side by a current, project to a great distance into the open sea, owing to the fresh materials which each new tide adds to the terminal point. It is thus that in less than sixteen years Cape Ferret has advanced about three miles across the channel by which the basin of Arcachon

Fig. 80.—Different Positions of Cape Ferret from 1768 to 1863.



communicates with the open sea. In 1768 the Cape was almost to the west of the basin properly so called. In the latter part of the eighteenth century, and at the commencement of the present, the winds from the north, which blow in those parts more frequently than the other atmospheric currents, had caused the dunes of the promontory to advance each year in a southerly direction, while the surf from the open sea, and the ebb of the basin, incessantly added fresh masses of sand to the point. In fifty-eight years, from 1768 to 1826, the Cape lengthened by above three miles towards the south-east, with an average speed of 94 yards per year, or about 8 to 10 inches per day. The point increased, so to say, visibly;

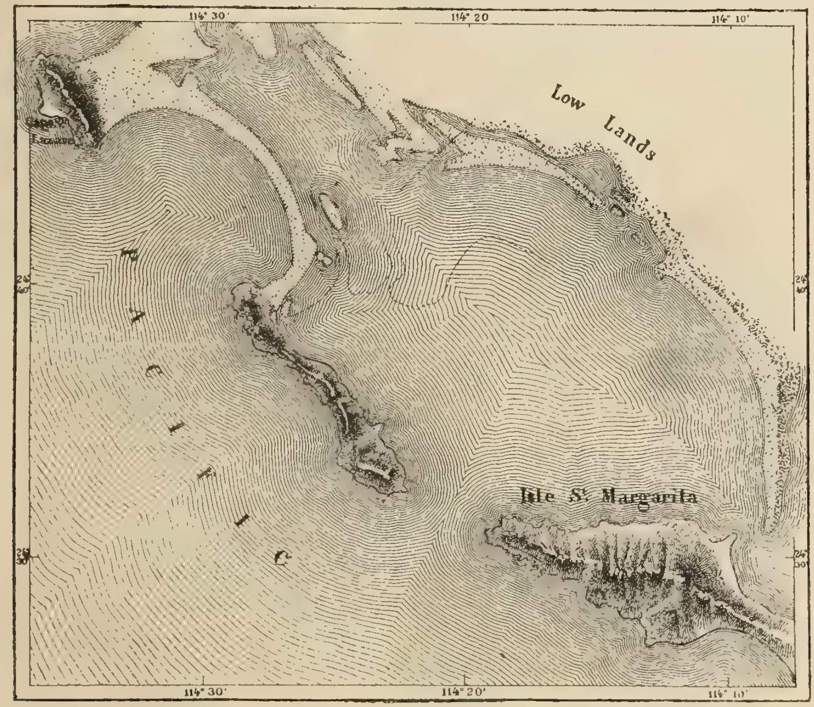
but a few years later the passage had suddenly changed its direction, and tending to the north, the tidal current commenced to wear away the peninsula, and gradually caused it to retreat towards the north-west. In 1854 the extremity of the cape had retrograded nearly $1\frac{1}{4}$ mile. It is said to be at present nearly stationary, but if the channel moves towards the south, which may happen any day, it is not to be doubted that the point of the cape would recommence encroaching upon the sea in the same direction.

CHAPTER XXI.

SHALLOWS OF THE COAST.—DEPOSIT FROM CALCAREOUS ROCKS.—APPEARANCE OF STRANDS AND BEACHES.

THE formation of shallows and sandbanks is connected also with that of littoral ridges; they are developed parallel to the shore, under the combined influence of the currents along the coast and winds from the open sea. A glance at a chart which indicates the form or those ramparts hidden under the waves, shows at once that all these invisible banks of sand and mud tend to elongate themselves in a straight line, or to follow graceful curves no less regular than those of the

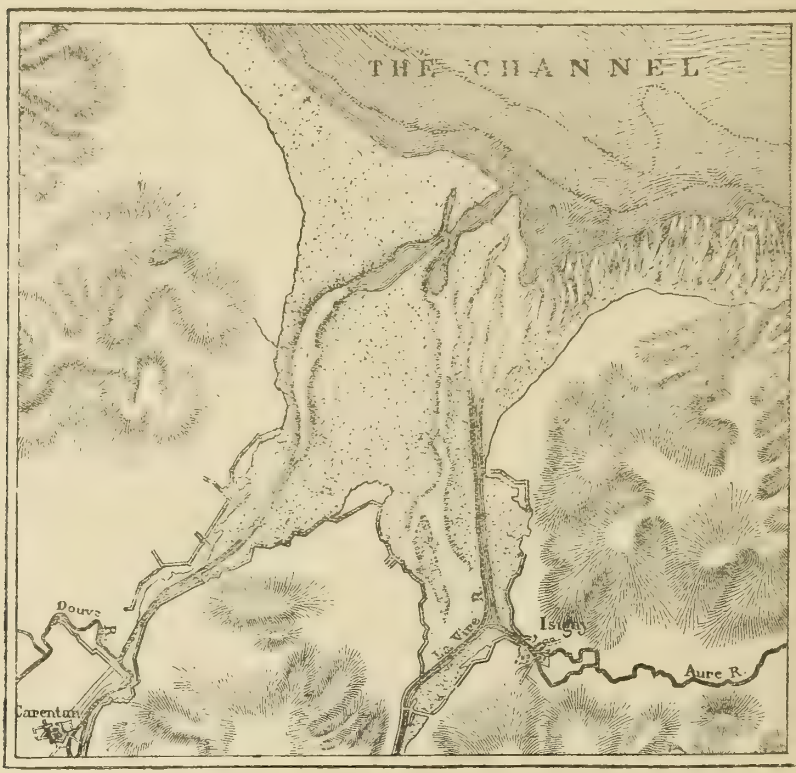
Fig. 81.—ROAD OF MADALENA. CALIFORNIA.



littoral ridges. In all the gulfs and straits on the coasts of California, the Carolinas, and Brazil, in the Channel and in the North Sea, there exist along the coasts a multitude of these banks, the arrangement of which indicates exactly the

path of the contrary or parallel currents which have been formed by their meeting. Their depth varies. There are some over which large ships can sail without danger; but there are others very near to the surface of the water, over which the waves incessantly break. It is these banks, hardly below the level of the sea, which are the most dreaded; and the English and American sailors, thinking of the fate that perhaps awaits them on these hidden sands, have gaily given them the ironical name of "frying-pans." In wide-mouthed gulfs, and along straight coasts, the sea endeavours to construct new shores by means of deposits of mud. The remains of seaweed and animalculæ, mixed with sand and clay, are deposited in deep layers along the coast, and cause the outline of the shores to advance gradually. Mud has been accumulated by hundreds and tens of thousands of

Fig. 82.—Gulf of Carentan.



millions of cubic yards since the historical era in the ancient Gulf of Poitou, in the Gulf of Carentan, situated at the foot of the peninsula of the Contentin, in the bays of the Marquenterre and of Flanders, in certain estuaries of the Netherlands and of Friesland. In these parts the sea and the land are mingled: the sea, gray or yellowish, resembles an immense slough, and continues the oozy surface of the shores; and one does not know where the water terminates, or where the plain of mud, incessantly stirred by the tidal wave, begins. Still the mud which emerges at low water is, little by little, heaped up and consolidated; a species of conferva covers its surface with a slight carpeting of a pink hue; then come the herbaceous salicernia, which contribute to elevate the soil by their stiff branches springing from the stem at right angles. To this first vegetation succeed other marine plants—

carices, plantains, reeds, and climbing trefoil. Then is the time to recover the oozy meadow for agriculture, and to connect it with the mainland by defending it with strong dikes against the assaults of the sea.

In the seas whose waters have a high average temperature, the waves do not confine themselves to constructing littoral ridges and filling up the bays; they even build actual ramparts of stone. In consequence of the rapid evaporation produced by the rays of the sun, the calcareous particles and mud contained in the water are gradually deposited along the shores and over the base of the promontories. Mixed with sand and fragments of shells, it tends to form solid shores with regular contours. On the Atlantic coast of France, at Royan for example, one can, here and there, already observe some formations of this kind; and further to the north, at Elsinore, some of these stones have been discovered, containing ancient Danish coins. On the French shores of the Mediterranean these modern rocks are very numerous, and in a short walk one can often collect a large quantity of sandy blocks and various conglomerates, united by calcareous substances, and containing multitudes of broken shells. The Museum of Montpellier possesses a cannon which was discovered near the principal mouth of the Rhone, imbedded in a calcareous deposit. On the northern coasts of Sicily, where the mean temperature of the waters rises to 64·4 F. the stones and pebbles of the shore are, in many places, agglutinated by calcareous cement. In the same way the fragments of rocks which the torrents of Arabia Petræa bring every winter from the top of the mountains to the shores of the Red Sea, are, in the space of a few weeks, converted into a stratum of solid conglomerate. Every year a new layer of stone is added to the old ones, and in future centuries we shall be able perhaps to estimate the age of the formation by the number of its beds, one above the other, in the same way as we recognize the age of a tree by the number of its annual rings of wood.

We must explore the shores of the Antilles, or other tropical seas, to observe this phenomenon of the formation of rocks in all its grandeur. There the waves, heated to 89·6 F. by the rays of a vertical sun, deposit limestone in sufficient quantity notably to increase the extent of the shore. The tufa of Guadeloupe, in which the famous human skeleton preserved in the British Museum was found, belongs to this recent formation. It grows, so to say, under the very eyes of the observer, and gradually covers with a rocky crust all those objects which the sea rejects, and which the brooks bring down from the interior. In many parts of the mainland these quarries of marine stone are actively worked for building towns on the coast, and all the excavations made in these banks of limestone are soon filled up by new materials. The quarry grows under the labourers who are occupied in detaching the blocks; hence the name of *Maçonne-bon-dieu*, which the natives have given to those rocks which seem to be renewed of themselves.

On the shores of Ascension Island Mr. Darwin found some of these conglomerates cemented by marine limestone whose specific weight was 2·63, that is to say, hardly less than that of Carrara marble. These beds of compact stone, deposited by the sea, contain a certain quantity of sulphate of lime, as well as the animal substances which are evidently the colouring principle of the whole mass. Sometimes the translucid stucco covering the rocks has the polish, hardness, and hue of nacre; moreover, as chemical analysis proves, this kind of enamel and the envelope of living molluscs are composed of the same substances equally modified by the presence of organic matter. Mr. Darwin observed some of these calcareous deposits, whose composition and nacreous appearance seem as if they ought to be attributed to guano saturated with salt water.

This construction of new shores, either by the sea itself or by the coral animals, like the gradual formation of the dunes, results in completely modifying the form of the coast, by separating from the rest of the sea large bays, which the rapid evaporation transforms later into firm land. It is thus that on the eastern coast of Africa the small Lake of Bahr-el-Assal, at the extremity of the Gulf of Tajura, has been separated from the sea by a slender ridge of sand, and dried up under the rays of the sun. Rain-water being very rare in this country, and the basin receiving no affluent, its waters have not been replaced, and now it is only a marshy hollow, the level of which is about 570 feet below the Red Sea. While they occupied the coast of Abyssinia during the last war, the English engineers

Fig. 83.—Bahr-el-Assal and the Gulf of Tajura.

discovered another basin, dried up and completely covered with salt, which was 189 feet below the sea-level. It is very probable, too, that the depressions in which the great river Hawash loses itself to the south of the plateau of Abyssinia, are likewise below the sea-level. The Isthmus of Suez formerly offered a phenomenon similar to that of the bank of Tajura. There, too, a lacustrine sheet, which previously formed part of the sea, had been enclosed by the littoral ridges, and had almost entirely evaporated. Only in our days the great inter-oceanic canal causes the marine waters to flow again through this dried-up lake. The ancient banks on the shores of the Mediterranean and the Red Sea, which the forces at work in the interior of the planet had gradually elevated to the height of several yards, have been pierced by engineers, and an artificial strait much more important for

Ocean

GEOLOGICAL MAP OF

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LONDON. J. S

RANCE AND ITS SEAS. PL. XI.

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human progress than the great arm of the sea was formerly, joins the Mediterranean with the Arabian Gulf.

If the great geological labours of the ocean, such as the erosion of cliffs, the demolition of promontories, and the construction of new shores, astonish the mind of man by their grandeur, on the other hand the thousand details of the strands and beaches charm by their infinite grace and marvellous variety. All those innumerable phenomena of the grain of sand and drop of water are produced by the same causes which determine the great changes of the shore. At the sight of the delicate lines which the dying wave traces on the beach, as well as in the presence of the wild coasts which the surf wears away in fury, we feel ourselves brought back by various impressions to the contemplation of the same general laws. Each wave accomplishes on its little portion of the shore a work similar to that of the great ocean on the outline of all the continents. In a space of only a few yards we can see developed the regular curves of small bays, littoral ridges raised, inland lagunes formed, and cliffs of shells and fuci eroded. At the extremity of certain sheltered bays—in the Bay of Beaulieu, near Nice, for example—black masses of from 3 to 4 yards in height may be seen, cut into peaks and pierced with caverns like rocks; these are masses of algæ.

Among the various marvels of the shore nothing astonishes us more at first than the designs traced on the sand often with perfect regularity. Every breaker brings with it shells, pebbles, and other fragments of all kinds and of different sizes. These objects are so many little reefs which divide the wave on its return to the sea, and cause it to trace upon the ground a network of intersecting lines. The surface of the strand presents in consequence an interlacing of innumerable lozenges, all ornamented with a shell or pebble at their upper end, and pointed or slightly rounded. All these little lozenges are themselves comprised within large quadrilaterals formed by furrows having, as starting point, an object of relatively considerable dimensions. Contrasts of colour aid in the relief to vary still more this varied aspect of the shore. The differently coloured materials being in general of a different specific weight, are distributed in a regular manner in the various parts of the lozenges. One side of the figure may be formed of small crystals of mica, while another is composed of black sand charged with peat, another of pink or yellowish shells, and the fourth of grains of a pure white. Sometimes the sand, impregnated with organic substances, shines like watered-silk, or is slightly iridescent, as if a very thin layer of oil were spread over the ground.

All these hues modify the aspect of the shores infinitely, and the greater or less inclination of the ground introduces yet a new element of variety into the network of lines. In all those places where the slope is considerable, the water hollows out the sands in the figure of miniature rivers with their tributaries and deltas. Besides, these small hydrographic systems themselves differ from one another according to the inclination of the ground and the weight of the grains of sand. In one place the sloping ground and the fineness of the displaced materials permit drops and streamlets of water to descend in a straight line towards the sea; in another the rivulets, making their way with difficulty between the obstacles that arrest them, flow in winding courses. Elsewhere, watercourses cannot even be formed. The water of the sea remains on a horizontal strand, and all the wavelets reproduce, in hollows or in relief on the sand of the bottom, all the movements which the breath of air impresses on them. There is no appreciable difference between the varied surface of the shore exposed freely to the wind, and that of the

sand which a thin watery bed covers, excepting perhaps that the furrows of the pool are more regular and deeply hollowed out.

Among the innumerable phenomena that might keep a geologist all his lifetime on the seashore, we must include a kind of miniature volcano. In breaking regularly on the shore, the wave brings each time a certain quantity of sand which it spreads in a thin layer. The air absorbed into the pores of the soil, immediately disengages itself in bursting bubbles; but here there are always a great number of aërial particles which cannot penetrate the damp bed of sand, and remain enclosed. Under the influence of the warmth of the ground or of the surrounding air, these particles dilate little by little, the pressure of the gas raises the hardened coating, and forms a cone, which sometimes bursts in consequence of the inward pressure, and throws out in volleys little spouts of sand-grains. It is true that unobservant persons walk over millions of these humble volcanoes without perceiving even one, but those who love the earth under all its aspects, and who contemplate with the same admiration the grain of sand and the mountains, can easily discover and study them. For the naturalist, who sees immense forests in every heap of algæ and a world of animals in the remains which strew the sand, the thousand wonders of the shore cannot fail always to awaken an intense pleasure.

CHAPTER XXII.

ORIGIN OF ISLANDS.—ISLANDS OF CONTINENTAL ORIGIN.—ROCKS OF THE SHORES.—ISLANDS OF DEPRESSION, ELEVATION, AND EROSION.—ISLANDS OF OCEANIC ORIGIN.—ATOLLS AND VOLCANOES.

ON viewing the great geological labours accomplished by the dash of the waves on the various coast lines, savants have often asked what is the share the sea takes in the formation of islands. Among the lands which are scattered over the surface of the ocean, some disposed in groups or series, and others completely solitary, how should we distinguish between those which the sea has detached from the continents, and those which have existed in an isolated manner from all times like separate worlds? Is it even possible in the present state of science to attempt a classification of islands, according to their origin? Yes, this work may be commenced. By calling to our aid the new resources which botany and zoology offer to physical geography, we may affirm that, sooner or later, we can indicate with certainty the manner of formation and the relative age of each oceanic country.

Firstly, it is evident that the islands, islets, and rocky ledges situated in the immediate neighbourhood of the coasts, are a natural dependency of the continents, and geologically make a part of them. At the base of the high mountains, which send far into the sea advanced capes, similar to the roots of an oak, we may see in many places, so to say, the crests of the lateral chains continue under the surface of the ocean. The outline of the continental heights sinks by degrees; to the mountains succeed the hills, and the promontory of rocks, whose escarpments plunge beneath the even surface of the waters. An inconsiderable strait, simply a hollow where the waves meet each other, separates the cape from a less elevated island. But further on there opens a wide channel, and the peak which shows itself at the surface on the other side of the submarine valley is no longer anything more than a needle of rock. Beyond stretches the open sea where the submerged ledges, if any still exist, are only revealed by the whitening foam. On all the abrupt coasts these islets belonging to the primitive architecture of the continent are very numerous, and even in certain parts form real archipelagos. Norway, Western Scotland, Chilian Patagonia, and all those countries where the fjords change the coast-line into an immense labyrinth, are thus bordered with innumerable islands, having likewise their indentations, their straits, and their girdles of islets. This is because, since the relatively recent retreat of the glaciers which filled all the space comprised between the circles of snowy plateaux and the exterior promontories, the original relief has but slightly changed. The terrestrial

alluvium brought down by the torrents has only filled up a small number of valleys; and the bases of the islands and capes, plunging deeply into the waters, have not served as support to marine alluvium similar to that which spreads along the low coasts. Isolated rocks, which the ice formerly surrounded as it now surrounds the "Jardin" of Mont Blanc, now rise in the midst of the waters, but they are not the less the salient points of the continental relief; in shallower waters, where the deposit of the marine alluvium would be easily accomplished, they would long since be joined to the shore.

Among the islands which may be considered as simple dependencies of the great neighbouring lands, we must also class not only those which the marine or fluvial alluvium has raised, simple emerged banks which are especially found along low coasts and near the mouths of rivers; but likewise the islands which are due either to the rising or gradual sinking of the ground. Thus, the chain of insular downs which defends the coast-line of Friesland and Holland against the assaults of the North Sea, from Wangerooge to the Texel, is most certainly the remains of the ancient shore, and it is this rather than the half-submerged beaches of the Dollart and the Zuyder Zee which marks the true boundary between land and sea. On the other hand, the coasts of the Scandinavian peninsula, which rise slowly above the waves, have been enriched with new islands during the course of the present geological epoch. In the maze of the Norwegian fjords, in the Lofoten Isles, in the archipelago of the Quarken, hidden ledges have become visible rocks, then extensive islands, where the algæ have been gradually replaced by a terrestrial flora. While the continent was encroaching upon the sea, the islets here and there have risen up and spread far over the waters like the leaves of some gigantic plant. The insular rocks rise slowly from the depths of the ocean, elevated by the same force which raises the neighbouring continent. And is not a like phenomenon accomplished on the coasts of Scandinavia? Perhaps even the large island of Anticosti, which extends in the Gulf of St. Lawrence over a length of more than 125 miles, is one of these slowly elevated lands, for, according to the testimony of Professor Yule Hind, one does not find in the granitic valleys of its rocks either serpents or batrachians, as on the coasts of Labrador and Canada. If it is really thus, we could hardly admit that Anticosti has ever been in communication with the continent of America; it must have emerged from the waters like the islets of the Scandinavian coast-line.

It has happened differently with regard to Great Britain and the greater part of the islands which fringe the outline of the continent. It is certain that England formerly made a part of Europe. This is proved by the perfect agreement between the shores on each side of the Straits of Dover; it is also proved by the fauna and the flora of the British Islands, in which all the animals and all the wild flowers are colonists from the neighbouring world; not a single species belongs peculiarly as its own production to the soil of old Albion. In the same manner, Ireland has been separated from Great Britain during the present geological period, and around the two principal islands, a number of secondary fragments, the Isle of Wight, Anglesea, and the Scilly Isles, have been similarly isolated in the midst of the waves.

A multitude of islands, situated, like England and Ireland, in the neighbourhood of continents, are also simply fragments which the waves, aided perhaps by the gradual sinking of the land, have detached from the shores of the mainland. The magnificent archipelago of Sunda, the Moluccas, and the neighbouring islands of Australia, present the most remarkable example of this breaking into

pieces of the continental masses. A channel, nearly 19 miles wide, and more than 109 fathoms deep, passes between the two large islands of Borneo and Celebes, and continuing in a southerly direction, separates the two volcanic countries of Bali and Lombok, very near to each other. This channel is the ancient strait which served as the common limit to Asia and the southern continent. To the west, Java, Borneo, Sumatra, the peninsula of Malacca, and Cambodia, rest on a submarine plateau, which lies hardly 33 fathoms below the surface of the waters: to the east, Sumbava, Florés, Timor, the Moluccas, New Guinea, and Australia, are likewise on a sort of pedestal, which sinks gradually, and upon which the zoophytes construct here and there long barrier reefs. Thus, as the naturalist Wallace has demonstrated by his researches in the Indian Archipelago, all the species of plants and animals differ completely on each side of the dividing channel. The fauna and flora are Asiatic to the west, while to the east they present the Australian type; even the birds, for whom a strait a few leagues in width would seem but a slight obstacle, are distinctly different in each of the two groups of islands.

We must therefore see in the Australian archipelagos the wreck of a great continental mass, which must have divided into numerous fragments at epochs more or less distant from our time. We may say as much of the islands of the Ægean Sea, of those of Denmark, of the Polar Archipelago in the New World, of the maze of the Magellanic Islands, and of the greater part of lands which surround the shallower waters in the neighbourhood of the coasts. As to the great islands of the Mediterranean, Cyprus, Crete, Sicily, Sardinia, Corsica, and the Balearic Islands, they are also very probably the remains of more extensive countries formerly united to those continents now known as Europe, Asia, and Africa. For though these lands, with the exception of Sicily, all rise from the depth of abysses having, on an average, from 500 to 1000 fathoms depth, nevertheless the fossil and living species of the Mediterranean Islands do not differ from those of the neighbouring continents, and it is consequently there that we must seek their origin. From a geological point of view, one can even say that the countries of the western basin of the Mediterranean, Spain, Provence, the Italian peninsula, Tunis, Algeria, and Morocco, form with the neighbouring islands a whole much more precisely defined than, for example, central Europe, from the Straits of Gibraltar to the shores of the Caspian. In spite of the depths which separated them, the coasts lying opposite to each other, on each side of the Tyrrhenian Sea, have preserved a similarity of physiognomy in the flora and fauna of the land.

The Mediterranean islands may thus be considered either as dependencies of the neighbouring continents, or, better still, as the remains of an ancient country partially swallowed up. Still, there exist in the midst of the sea insular masses in which geologists see nothing else than the witnesses of continental tracts which now have disappeared. Thus Madagascar, though sufficiently near to Africa, seems a sort of separate world, having a flora and fauna belonging peculiarly to itself, and even possessing entire families, especially of serpents and lemurs, which have no other representatives on our planet. Strange to say, even the island of Ceylon, half united to Hindostan by the rocks, islets, and sandbanks of the Rama's Bridge, differs much from the neighbouring peninsula by the general aspect of its animals and plants, and we may question if, instead of being simply a dependence of Asia, it is not, on the contrary, the last remains of an ancient continent which extended over the area of the Indian Ocean, and comprised Madagascar, the Seychelles, and other islands now almost imperceptible on the map.

Among the fragments of vanished worlds, we ought also probably to class the greater part of the Antilles and New Zealand. The larger Antilles present a much more striking contrast with the countries of North America than that between Ceylon and the peninsula of the Ganges. By elevation and geological character, Hayti and Jamaica do not in any wise resemble the low lands of the American coast, situated on the other side of the gulf; their vegetable and animal species differ notably from those of the neighbouring continent, though winds, currents, birds of passage, and even man, have worked together for an unknown number of centuries to carry animals and plants from one shore to the other. As to New Zealand, it is quite a distinct world, whose flora and fauna have an essentially original character. Neither the fossil nor the living species resemble those of Australia or South America. And the great number of savants agree with the opinion of Hochstetter, who sees in New Zealand and in Norfolk Island the fragments of a continent isolated ever since the commencement of the Mesozoic period. While Great Britain may be considered as a type of the islands scarcely separated from the neighbouring continent, her fine colony at the Antipodes represents, on the contrary, an ancient world, gradually reduced by subsidence and the erosions of the sea to the dimensions of a mere insular group.

The land of the oceanic islands is of small extent and differs widely in the nature of the rocks, as well as in the character of the terrestrial and marine fauna and flora, from the continents and continental islands. There has not been found in the abysmal areas any land made up of gneisses, schists, sandstones, or compact limestones; nor have fragments of these sedimentary formations been found in the erupted rocks of the volcanic islands, though they are frequent in the volcanic eruptions on the continental areas.

We may, indeed, compare the oceanic islands to the fresh and salt water lakes scattered over the surface of the continents and cut off from direct communication with the ocean. These lakes differ as much from the waters of the ocean as do the oceanic islands from the land of the continents.

The present shape of islands often allows us to recognize what was their earlier form when they extended over a much more considerable space. By their outline and ramifications, the mountain-ridges indicate in a general manner the first configuration: they are as the fragments of a skeleton around which we reconstruct, in thought, the contours of the ancient continental body. Besides, many of these, of which only the primitive skeleton remains, and whose plains have disappeared, are indented in the most curious manner, and their shores often present the most fantastic outlines. Thus, Choa-Canzouni, in the Archipelago of Comoro, is a group of two large islands united by a sort of stalk; Nossi-Mitsiou, in the same region, resembles a trunk with two broken boughs; finally, Celebes and Gilolo, so remarkable by the parallelism of their gulfs and promontories, seem to be both constructed on the same model; and what we know of the mountains of Borneo allows us to believe that if this large island were to be submerged beneath the sea, its shores would resemble, by their contour, those of its two neighbours in the sea of the Moluccas.

Besides these fragments of ancient or modern continental masses, all the projections which show themselves above the level of the ocean are either built by zoophytes, or else cast up by volcanoes from the bottom of the sea; one or the other is, without exception, the origin of all these islands. The first, as we know, are disposed in *atolls*, or annular reefs, formed themselves of rings of smaller dimensions; while cones of lava, that are elevated in the open sea, rise proudly above the

waves, and reveal the independence of their origin by a declivity which is continued pretty regularly below the waters. Still we can see by the example of the volcano of Stromboli, and more plainly still by that of the island of Panaria, that the waves constantly lessen the submarine slopes by distributing to a distance the lava and cinders rejected by the craters.

"When the coral atolls and barrier reefs which are scattered over the tropical regions of the great oceans are examined in the light of recent discoveries, it is

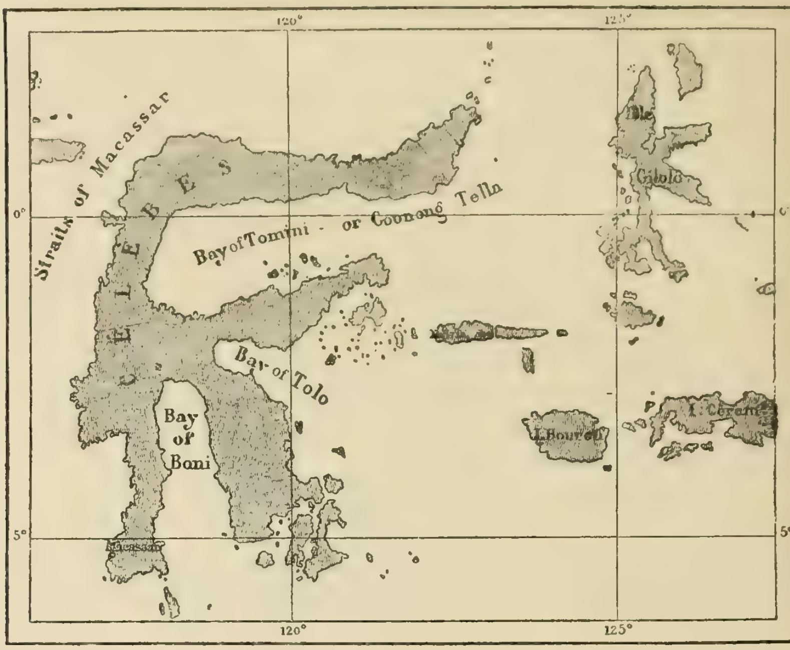
Fig 84.—Nossi Mitsiou

found that their peculiar form and structure can be accounted for by the truncation of some submarine cones through breaker action; by the upward growth of others through the accumulation of marine deposits; by the solution of dead coral through the action of sea-water; and lastly by a study of the source and direction from which the food supply reaches the reef-building animals. That this in all probability is the true history of the origin of these marvellous structures is further confirmed by the recent examination of the upraised coral atolls of the Pacific by Dr. Guppy, and the researches of Mr. Buchanan into the characters of oceanic

banks and shoals. Coral atolls and barrier reefs, instead of pointing out great and general subsidences, must be regarded rather as indicating areas of great permanence and stability.

"The results of many lines of investigation, then, seem to show that in the abysmal regions we have the most permanent areas of the earth's surface, and he

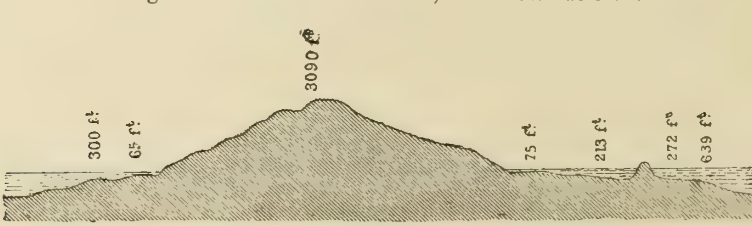
Fig. 85.—Celebes and Gilolo.



is a bold man who still argues that in Tertiary times there was a large area of continental land in the Pacific, that there was once a Lemuria in the Indian Ocean, or a continental Atlantis in the Atlantic." (*Murray.*)

Compared with the lands of continental origin, the truly insular masses composed of lava, or built by the coral animals, have relatively a very slight extent.

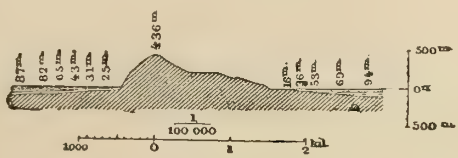
Fig. 86.—Section of Stromboli, from S.W. to N.E.



It seems that, according to the general arrangement of the globe, the separation must at first have been much more marked between the sea and the emerged lands. On one side great continuous countries, on the other desert oceans, appears to have been the natural distribution. But the incessant work accomplished on our planet, as on all the stars of heaven, has infinitely modified the form of the continental surfaces and the channels which separate them. In the same way as by its rains

and snows the sea has scattered lakes over the regions raised above its level, and traced the innumerable valleys of the watercourses, so have the lands given to ocean those myriads of islands and islets which vary its surface so gracefully. The alluvium of the rivers, the erosive power of the waves, the internal forces, which slowly raise or depress vast countries, or cause cones of lava to spring up suddenly from the deep; finally, the numerous organisms which assimilate the various substances contained in sea-water, have all worked in concert to scatter here and there

Fig. 87.—Section of Panaria, from N.W. to S.E.



islands of different forms and sizes, some in larger, and others in smaller groups, or even completely isolated. Later, the winds, rains, monsoons, and other meteoric influences of the atmosphere; the oceanic currents, the ebb and flow, the undulation of the waves, all which moves and floats in the water and in the air, birds and fish, seaweed and drifted wood, foam and dust—have never ceased to act directly or indirectly, to introduce life into these islands, to people them with species of animals and plants, and thus to prepare them for the abode of man.

CHAPTER XXIII.

DUNES RESULTING FROM THE DECOMPOSITION OF ROCKS.—FORMATION OF MOVING DUNES ON THE SEA-SHORE.—SYMMETRICAL DISPOSITION OF RIDGES OF SAND.

IT is principally upon the sandy beaches of the ocean that those changing hillocks known under the name of *dunes* rise in long rows. Nevertheless, the phenomenon of the elevation of the sand in moving hills may also occur at a great distance from the present sea-shore. Dunes are formed on all points of the globe where the wind finds and drives before it light sandy materials; but we must remark that these substances only exist in considerable quantities on the shores of the sea and large lacrustine basins, at the bottom of ancient gulfs and straits transformed into deserts, on the banks of rivers which roll sand along their beds and which are exposed to frequent changes of level by the alternation of droughts and inundations. It is the waters which, by their destructive action on the cliffs, prepare the sandy particles necessary for the construction of dunes; and this origin allows us to consider the shifting ridges of sand, whatever be their distance from the shore, as products of the ocean.

In all the great deserts of Asia and Africa, we see some of these terrestrial waves caused by aerial currents. Some exist also on the banks of the Nile and other great rivers. Even in France very fine dunes about 30 feet high rise on the banks of the Gardon immediately below the celebrated Roman bridge; it is the mistral which has raised them. In leaving the gorge that encloses it, this wind seizes the particles of fine sand left on the shores and dried by the sun, and deposits them at the entrance of the plain, where it spreads over a wide extent, and loses in intensity what it gains in surface.

A certain number of dunes have been formed on the spot during the course of centuries by the disintegration of freestone rocks. Fogs, rains, frosts, and other atmospheric agents, gradually wear away the stone and transform it into sand, which, falling, leaves fresh beds at the surface. These are subject in their turn to the destructive meteoric influences, and it is thus that the rock, once solid, is gradually changed, often to a considerable depth, into a mass of crumbling sand. The grains, chafed against each other during their fall, become finer and finer, and when the wind is high it can carry away these sandy particles, cause them to ascend the slope of the talus, and sometimes even raise them in clouds like the smoke of a volcano. Nevertheless, the dune, still enveloping a solid kernel and composed in great part of grains heavier than those of the sea-coast, is not entirely displaced by the action of storms; it only takes another form in consequence of the gradual

change of its slopes. Several mountains of this kind near Ghadamès, which were formerly rocky hills, rise to 150 and 600 feet high. One of them, which is not less than 510 feet, has an inclination of 37 degrees on the side exposed to the wind; nearly the greatest slope that a talus of sand can present.

As to dunes properly so called, those which are found far in the interior of continents cannot be compared in importance with those which are developed in long ridges parallel to the sandy shores of the sea. On the strands of the ocean which are not rocky, the existence of dunes is almost constant; the only low shores which are destitute of them are those which the waves have formed of clayey substances, of compact mud, or sand much mixed with animal and vegetable detritus. The sandy shores of the Mediterranean, of the Baltic, and other inland seas, where the tides are hardly preceptible, also present very insignificant dunes, because the want of ebb and flow does not allow the sand to acquire sufficient mobility. We see, however, some more than 90 feet high between Vera Cruz and Tampico, on the shores of the Gulf of Mexico, where the tides are very slight. On all oceanic coasts, the sand of which is loose enough to allow itself to be raised by the wind, the formation of dunes is accomplished with perfect regularity.

These hillocks rising, so to say, beneath the very eyes of the observer, it is not difficult to follow their progress, nor to offer a theory regarding them. The waves constantly agitating the shifting foundation of the shore, become charged with arenaceous matters, and spread them in thin layers over the strand. Then, at low

Fig. 88.—Formation of a Dune.

tide, the grains of sand soon become dry, and cease to adhere to each other, and thus allow themselves to be carried towards the land by the wind from the open sea. These are the materials of dunes. If the shore rises towards the interior of the continent in a perfectly even manner, this sand, cast up by the waves above the sea level, and carried far by successive gusts of wind, would extend over the ground in layers of uniform thickness; but the inequalities of the surface prevent this. Pebbles, branches and trunks of trees covered with shells, plants, and bushes with tough roots, project above the beach, and oppose the advance of the wind, which glides over the ground, carrying the grains of sand that have remained on dry land. These slight obstacles suffice to determine the origin of dunes by obliging the breeze to let fall the little cloud of arenaceous or calcareous dust with which it is charged. The horizontality of the shore is thus interrupted; rows of sandy knolls, which are subsequently to rise to real hills, commence to be traced upon the ground.

When the wind from the open sea blows with sufficient force, we can not only witness the growth of the dunes, but we can also aid in their formation, and verify by direct experiment the assertions of theory. If we deposit some object on the ground, or, better still, thrust a row of stakes into the sand, perpendicularly to the direction of the wind, the current of air which strikes against the obstacle will instantly rebound to form an eddy or whirlpool, the diameter of which is always proportioned to the height of the stake. Arrested by this eddy, the grains of sand

carried by the wind are gradually deposited on the near side of the barrier, till the summit of the miniature dune is on a level with the imaginary line leading from the shore to the upper end of the obstacle. Then the sand driven by the breeze from the sea, which ascends the inclined plane presented by the front of the hillock, no longer allows itself to be carried in the eddy and brought back; it crosses the little ravine which the gyration of the air has produced in front of the palisade, and falls beyond it to accumulate gradually on the other side of the obstacle, taking the form of a descending talus (Fig. 90). It is due to the knowledge of these facts, that we are able to force the elements to construct a protecting rampart of dunes on various points of the coast threatened with erosion by the waves of the sea.

Such is always the commencement of dunes, whatever be the object which opposes itself to the wind. It is easy to convince oneself of this by the sight of the houses or huts which the Custom House officers and shepherds erect in the sandy hollows of the dunes of the Landes not yet fixed by seedling trees. On the side towards the sea, which is also that from which the wind blows in terrible gales, the dwelling remains separated from the talus of sand by a ditch of defence, as regular as if it had been hollowed out by the hand of man; but on the side which

Fig. 89.—Formation of Sand Dunes.

fronts inland the sand is gradually heaped up, and if it is not swept away, does not fail to rise soon to the level of the roof.

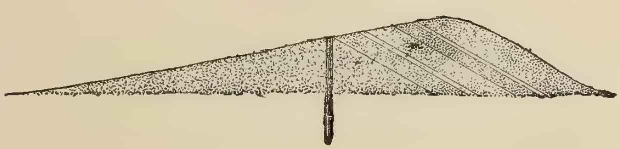
On the slightly undulating plateau which extends at the foot of the grand pyramids of Egypt, we can also study the same phenomena. The winds from the east and north-east, which strike against the eastern face of the enormous masses of stone, rebounding and developing their reflected waves on the ground, do not allow the sand to be deposited on the lower steps of the edifices. It is only at a certain distance, at the precise spot where the current is neutralized by the masses of air coming directly from the east, that the dunes can form. To the west of the pyramids, on the other hand, long mounds of sand, more or less inclined, support themselves against the base of the monuments. In the same way, at the foot of certain cliffs of Liguria, where the sands accumulate in dunes, there always exists a sort of trench between the rock and the moving heap.

When the labour of man does not intervene to arrest the progress of the dunes formed on the sea shore, the various obstacles which have determined the accumulation of the sands disappear at first on the descending side under successive beds; then when this part is entirely hidden, the front in its turn begins to be buried. The wind, instead of developing itself according to a horizontal plane, as on the surface of the ocean, is obliged to take an oblique direction to ascend the slope of the dune. As soon as it is sufficiently elevated, the atmospheric current passes freely above the obstacle which arrested it before, the little eddy which revolves in front ceases its gyrations, and nothing then hinders the sand from gradually filling up the ravine which the aerial current had maintained in front of the barrier.

Soon the summit of the dune coincides with that of the obstacle: the latter disappears completely, and the hillock, growing like a wave which approaches the shore, and constantly raising its crest higher, which is incessantly displaced, continues to encroach upon the land. The various strata of sand which the wind from the open sea successively brings to the summits of the dunes, spread in large sheets over the descending talus, and glide down to the base. In the Landes of the Gironde the western slope of the dunes, whose base is not worn away by the sea, is, on an average, from 7 to 12 degrees. The eastern slope, which is that of the descending talus, is from 29 to 32 degrees; that is to say, three times as great. It would be 45 degrees if the rains did not make ravines in the talus and thus prolong the inclination.

Thus the dunes incessantly gain, owing to the new layers of sand added to their changing talus. But the action of the prevailing wind does not limit itself to increasing them; it ends by displacing them entirely, and making them, so to say, travel over the ground. The object at the base of which the eddy of air had deposited the first grains of sand is at length decomposed; inclemencies of the weather, insects, moisture, and chemical agencies destroy it, and when it has disappeared the sand which it retained shifts again. The wind, which only carried away the superficial beds of the dune to replace them incessantly by new

Fig. 90.—Section of a Dune.



sheets of sand, can now carry away all the anterior part of the hillock; it lengthens the descending talus at the expense of the shore side, and the base of the hill, worn away by the wind, constantly retreats from the shore. The dune is on the march; it advances inland. Such is the mobility of the sands that even when the waves erode the foot of the dune, and force it to fall into the sea, the summit does not the less advance towards the continent. Destroyed on one side, it invades on the other, like those voracious insects which, even when cut in half, do not cease to eat. The high dunes of Lagrave, to the south of Archachon, are the most curious in this respect; below, the sea forces them to fall in; above, they bury the pine-trees in their invading masses of sand.

The most favourable days for observing the progressive march of dunes are those when a gentle breeze, strong enough however to drive the sand before it, blows in a perfectly uniform manner. From the top of the dune we see innumerable grains of dust swiftly scaling the slope. Glittering in the sun, and whirling like midges on a fine summer evening, they attain the summit, then accumulate in the form of a cornice on the other side of the ridge, and from time to time occur little falls, which spread over the surface of the talus, like sheets of water over the sides of a rock, and whose contours remind one of light draperies covering one another. When a high wind blows with violence, and in successive gusts, the encroachments of the dune are accomplished in a manner much more rapid, but often much more difficult to observe. The summits of the hillocks, which are enveloped in clouds of dust, resemble volcanoes vomiting smoke; the front of the dune is furrowed and scooped out by the wind; masses of sand, laden with marine

remains brought by the storm, fall down with an audible sound, and are disposed in unequal layers over the descending talus. A section taken across a dune would permit us to count and measure the different strata, varying in thickness and composition, which the winds have successively brought. Here we find a fine sandlike dust; there, a stronger wind was charged with a heavy shelly sand; while, again, a storm has carried away entire shells, branches, and waifs. However, the particles transported by the wind are, in general, all the finer the further they are from the sea, and this is reasonable, for they must fly more easily the less resistance they offer to the aërial current which bears them. In the narrow rows of dunes which border certain parts of the coast of the Mediterranean, we can clearly see over a breadth of some hundreds of yards, the moving materials succeed each other, distributed according to their weight. First, there are the fragments of shells, then the large arenaceous débris, then the fine sands.

If the inclined plane which the dune turns towards the sea remained perfectly even, the zone of the shore would only present, in all its extent, a single rampart of sand gradually encroaching on the lands. But at length the slope of each dune cannot fail to offer some inequalities caused by foreign bodies, or by plants that take their origin in the sand. All the salient points strong enough to resist the wind serve as supports to new dunes, grafted, so to say, on the sides of the ancient one. These new dunes themselves bristle with irregularities, which other sand-hillocks soon cover, and it is thus that all those ranges of moving hills arise, which are separated by long and narrow valleys, called *lettes* or *lèdes* by the peasants of the French Landes. In certain places, especially between Biscarosse and La Teste, these lettes, for a length of several leagues, resemble the dried-up beds of large rivers, surrounding large islets of verdure with their sandy waves.

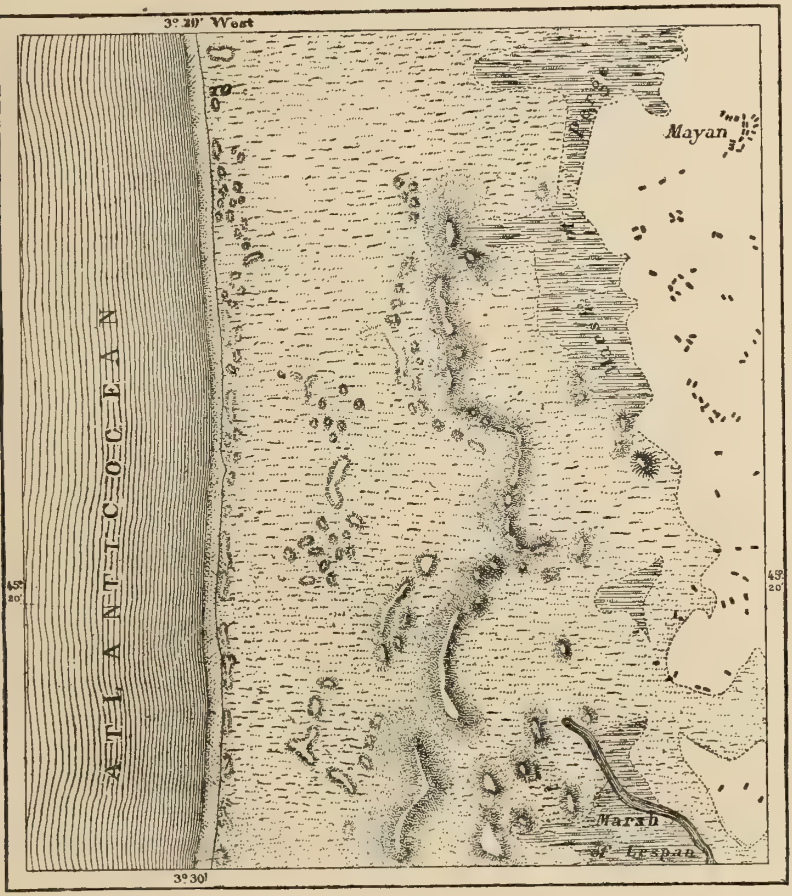
Notwithstanding the apparent disorder of these hillocks, in the midst of which an inexperienced traveller might easily lose his way, the general disposition of the sands can be always referred to a uniform type, which local geographical facts variously modify, such as the contours of the marine shore, the nature of the soil, the force and direction of the winds, the presence or absence of vegetation. The dune nearest to the sea, and, in consequence, the most recent, is less elevated than the older hillock situated immediately beyond; and this, in the same way, attains a less considerable height than the following hill. In a system of dunes, generally each range which is developed further inland exceeds the preceding ones in elevation and forms, as it were, a new step on the slope of the great primitive dune which serves as an *avant garde* to the army of sands. This last dune, the true crest of the entire system, enlarges itself, little by little, with all the materials which have served for the formation of the inferior dunes situated on the side nearest to the sea. The grain of sand which the air carries to the summit of the first hillock, and which falls afterwards into a ravine, may remain during centuries under the superincumbent masses; but owing to the constant progress of the dune, the superficial layers of which are swept by the wind, and then let fall by it further down the talus, this grain of sand at last reappears, is carried anew to a summit, it descends again, and thus does not cease to travel from dune to dune, to the last.

As the innumerable arenaceous particles are moved by virtue of rigorous laws, we can consequently measure the force of the winds by the height of the mass and the rapidity of the displacement of the hillocks. Attentive observation permits us, in the same way, to compare with each other the various atmospheric currents which drive the sands onward, and to indicate exactly the one whose action

is the most energetic. Thus, in the Peninsula of Arvert or La Tremblade, situated between the mouth of the Gironde and that of the Seudre, the chain of dunes rises gradually in a northerly direction, and it is at the northern extremity that the highest hillock is found. This phenomenon is explained by the frequency and intensity of the south-west wind which blows in these part; in virtue of "the parallelogram of forces," it carries the sand farther and higher than the winds form the west and north-west can.

Every isolated dune assumes clearly-defined contours resembling those of a crescent. It is easily understood why the hill must advance in such a manner as

Fig. 91.—Crescent-shaped Dunes.

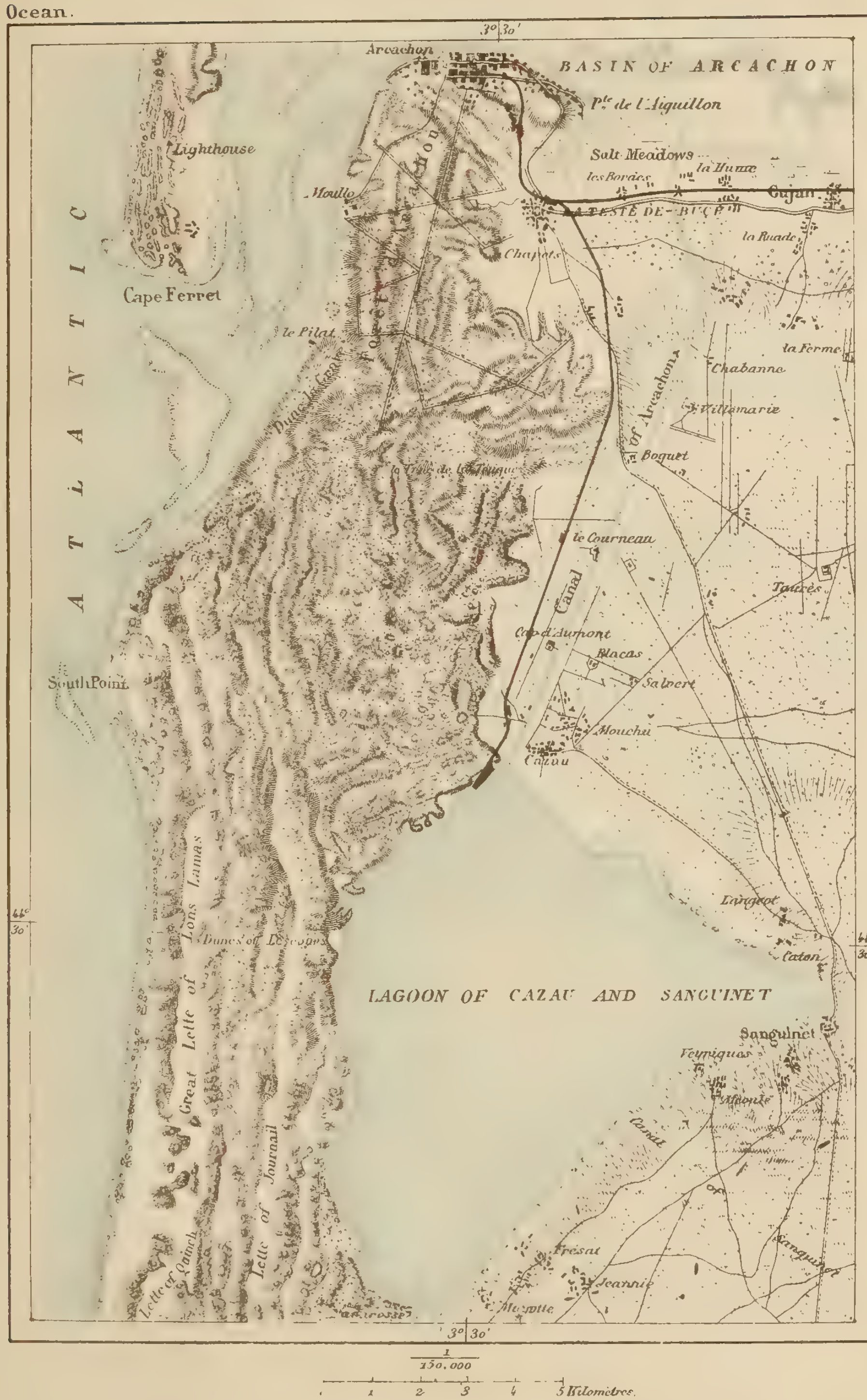


to project a curved point on each side of its principal mass. The grains of sand which the wind causes to ascend the height of the central part of the dune have to describe a longer path and to slide farther down the counter-slope than the particles of the two lateral extremities. They proceed consequently with less speed; the ends, exceeding in rapidity the rest of the dune, bend forward, in the shape of advanced horns, and give the whole of the moving hill the aspect of a volcano whose crater has fallen in. That which contributes still more to cause these sandy hillocks to assume this semi-circular form is, that the prevailing wind does not always blow perpendicularly to the mass of the dune. Its direction is often

oblique; now in one direction, and now in the other. It then makes the wings of the dune, the crest of which it strikes at right angles, advance more rapidly.

In the desert of Atacama, the Pampas of Tamarugal, in the plains of Texas, in the Sahara of Algiers, in the Nubian deserts, and in almost all the regions traversed by shifting sands, the crescent-shaped dunes present such a regularity of form that all travellers have been struck by it. The Landes of Gascony also offer remarkable examples of this semi-circular arrangement of the crest of the dunes. In the environs of Arcachon and La Teste all these hillocks have the appearance of fallen-in volcanoes, and are distinguished by the rich vegetation of broom and bushes which fill their craters or *crouhots*. In those parts of the coast of the Landes where the crater-shaped form of the dunes is obliterated, it is evidently because two or more hillocks have been united, and, so to say, amalgamated by the impetuous wind which blows from the sea. However, we can account to ourselves for all these phenomena by studying the little swellings of sand, or miniature dunes, which are formed in thousands on the marine shores.

THE DUNES OF THE TESTE IN 1876



CHAPTER XXIV.

HEIGHT OF THE HILLOCKS.—ADVANCE OF THE DUNES.—DISPLACEMENT OF "ETANGS."—DISAPPEARANCE OF VILLAGES.

IN Europe the highest hillocks of sand are found on the coast-line of the Netherlands, on the Atlantic coasts of France, and in Scotland on the shores of the Firth of Tay. As to the dunes of the Mediterranean, they are generally lower than those on the coast of the ocean. The gulfs of the south of Europe having a hardly perceptible tide, their sandy shores are not incessantly displaced like those on the strands of the ocean, and consequently they are less exposed to the winds which drive before them the finest particles. It is to the north of Africa, round the gulfs of the Syrtes, where the ebb and flow have the greatest development, and where sandy beaches occupy vast tracts, that the Mediterranean dunes attain the most considerable height. In France, those that are seen from Port Vendres to the mouths of the Rhone, hardly rise to more than 18 or 21 feet in height, because the banks on which these hillocks are formed have not a sufficient breadth, and above all, because the prevailing wind, the mistral, blows from the north-west, and carries the sand from the *étangs* into the Mediterranean.

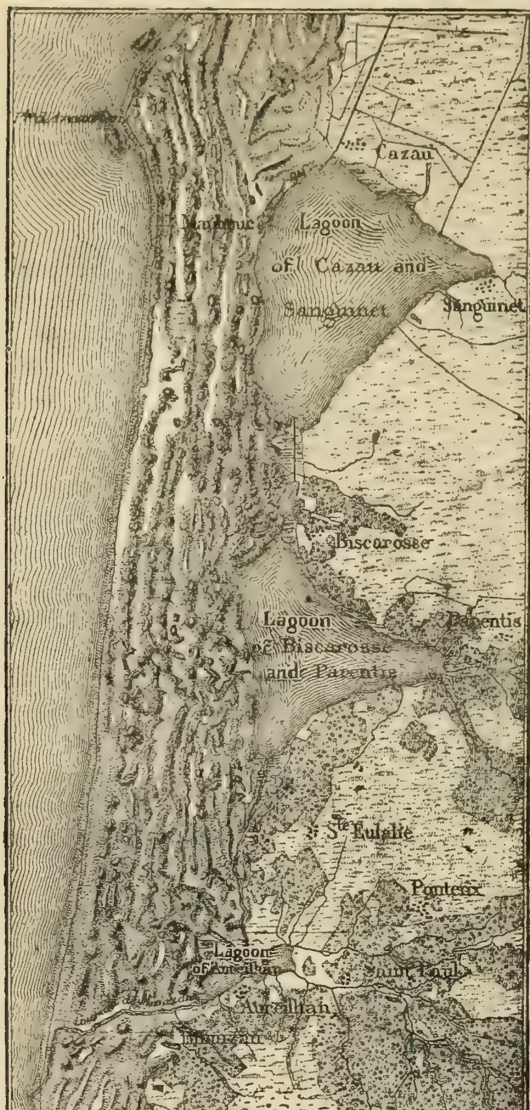
On the coast of the Landes of Gascony, where the waves of the sea bring six millions of cubic yards of sand each year, a great many dunes exceed the elevation of 225 feet. There is even one, that of Lascours, whose long ridge, parallel to the sea-shore, attains 261 feet in several places, and raises its culminating dome to a height of 291 feet. It is true that this height seems to mark in France the extreme limit of the ascent of the sand, for the ranges of dunes situated to the east of the dune of Lascours, are far less elevated. One would be tempted to admit that, after having arrived at this great height, the lower strata of wind from the west, compressed by the more elevated masses of air, have not the necessary power to cause the particles of sand to mount again, and are obliged to descend towards the plains of the interior, taking the crests from the hills previously formed. In Africa, on the low shores where the ocean bathes the great desert of Sahara, the enormous quantity of sandy materials that the eastern winds bring from the desert, and which the west wind drives back to the interior, permit, it is said, the dunes of Cape Bojador, and Cape Verde to attain an elevation of from 390 to nearly 600 feet.

The highest dune in the New World is perhaps that of Morro-Melancia, near Cape St. Roch, nearly 150 feet high; it rests on one side against a wooded hillock.

To the eyes of a traveller accustomed to the ascent of the Alps and the

Pyrenees, these are very humble summits; yet these heights of sand assume the aspect of actual mountains, and their chains, arranged parallel to the shore, like ranges of enormous waves, seem to constitute an entire orographical system. Their bold taluses, their solid ridges, cut as with a chisel, the regular form of their tops, the general harmony of their contours, unceasingly varied at the will of the wind, give them an astonishing appearance of grandeur. The very even base-line which the sea-shore presents likewise adds to the illusion by contrast, and contributes to the grand aspect of these white hills. The old name, at once Celtic and Latin, of the dunes (dun), which was applied to mountains and steep hills, and which we still find in the names of several towns — Verdun, Loudun, Issoudun, Saverdun — proves that our ancestors had been singularly struck with the bold form of the sandy hillocks of the coast.

Fig. 92.—Lagoons of Cazau, Parentis, and Aureilhan.



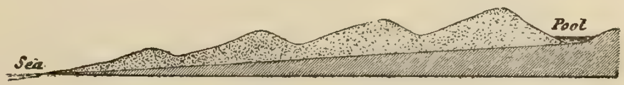
While gaining incessantly on the plains of the interior, the dune buries, without destroying, all solid objects — stones, rocks, trunks of trees, or human dwellings. Sometimes even it entirely covers pools of water, and causes them to disappear for some time under its sloping talus. When the sand brought by the wind falls regularly on a sheet of water, stagnant or covered with scum, it often forms a fine layer, completely veiling the water which bears it, from view. This bed can become solid enough to remain in equilibrium even when the level of the sea falls below it, and soon the particles of sand, dried by the solar rays, no longer betray the existence of the hidden pitfall. The herdsman or animals which set foot on the surface of the *blouse* are suddenly engulfed more or less deeply, and the waters of the pool rise around them. Most frequently they escape with the fright. Little by little the crumbling sand is heaped up; they allow the bottom to be consolidated, then quietly raising one leg, they wait till a sort of step is formed, and thus mount from stair to stair.

If little pools are sometimes apparently swallowed, the more considerable masses of water, situated at the base of the dunes, are continually driven back into the

interior. The rivers, arrested in their course and changed into marshes, are also forced to retreat, and mix their waters with those of the pools. This formation of lakes and marshes, parallel to that of the dunes, is one of the most remarkable features of the coast-line of the French Landes. A row of ponds, differing in form and size, but all situated at a nearly equal distance from the sea, is prolonged over a space of 125 miles. One large bay, the basin of Arcachon, has been able to maintain a wide communication with the ocean, owing perhaps to the river which it receives from the interior. But all the other sheets of water, to the north the étangs of Hourtin and Lacanau, and to the south those of Cazau, Parentis, Aureilhan, St. Julien, Leon, and Soustons, only communicate with the sea by tortuous and rapid streams, and are now at a level considerably higher than that of the sea.

The étang of Cazau, the most elevated of all, and that which has been driven gradually inland by the strongest dunes, spreads its sheet of water at an altitude varying from 63 to 66 feet, according to the seasons. It has not less than 14826 acres of mean superficies. The spectator who contemplates it from the top of a hillock would think he saw a vast marine bay, for a great part of the opposite shores escapes the eye, and the isolated trees which mark afar off the distant bank, resemble a fleet of ships at anchor in a road; the white boulders of sand, of a triangular form, which are perceived at the foot of the green dunes, and which appear like so many sails of ships skimming along the coast, increase the illusion. Nevertheless, it is probable that the étang of Cazau was formerly a gulf of the

Fig. 93.—Formation of Lagoons.



ocean, for the bottom of this small inland sea is still found to be 36 feet below the marine level. The fishermen—who are the best authorities in such matters—uniformly attest that in the lowest parts of the pond, the lead touches the sand at 15 fathoms. They also assert that it formerly communicated by deep trenches with the sea, and they even indicate the bay of Maubrucq as having been the ancient port, and trace the direction followed by the channel in the middle of the dunes. In the same way, the fishermen of the étang of Hourtin still show the site of the old port of Anchise.

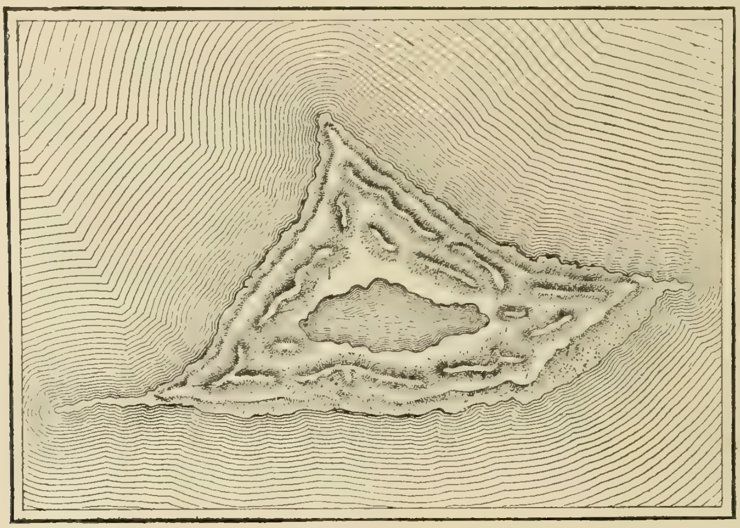
It is easy to explain the gradual transformation of the ancient Gulf of Cazau and other marine bays, which indented the now uniform coast of the Landes. Separated from the ocean at first by a slender ridge of sand, as is often formed on low beaches, these bays which are changed into ponds, have been gradually driven inland by the parallel rows of dunes. Under the enormous pressure of the sand they have climbed, so to say, the slope of the continent. At the same time the rains and rivulets, arrested in their course, have incessantly brought their contribution of fresh water to the new lakes, while the salt water retreated gradually by natural channels between the hillocks. Thus the grains of sand which the wind drives before it have sufficed, in the course of centuries, to change gulfs of salt water into ponds of fresh water, and carry them into the interior of the continent, to a height considerably above the Atlantic.

The same phenomena occur also in the sandy islands which are found in the middle of the sea. The greater part of these islands have a perfectly regular form,

due at the same time to the currents which bathe them, and to the winds which form the dunes. In the centre of the triangular or crescent-shaped space which they surround with their moving hillocks, they enclose one or several ponds, which formerly were a part of the sea, and which have transformed themselves by degrees into pools of saltish and finally fresh water. In Sable Island, situated not far from the mouth of the St. Lawrence, we can observe this phenomenon of transition actually in progress. While the large lagoon of the interior, too extensive to be rapidly purified, is still filled with salt water, the small ponds lying between the dunes are already fresh water.

Numerous have been the disasters occasioned by the invasion of dunes or ponds during the historic era. The villages situated at the eastern base of the dunes of Gascony, on the shores of the ponds, must be moved from time to time towards the east, for fear that they should be swallowed by the sands or the waters. At the approach of the danger the threatened inhabitants sometimes attempted a vain resistance. As soon as an east wind succeeded to the regular winds from the west,

Fig. 94.—Seal Island, in the Caspian Sea.

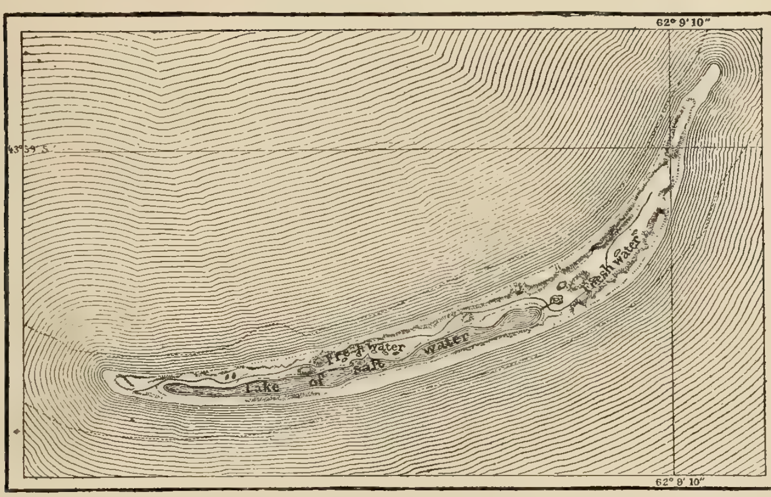


herdsmen and labourers, armed with spades and pick-axes, repaired in all haste to the top of the dunes, and, filled with a purposeless ardour, they destroyed the crest of sand, and delivered it to the power of the wind. But the regular winds soon brought back the sand again, the dunes recommenced their advance, and routed the army of peasants. For fear of being buried, they were obliged to destroy their huts, in order to carry away the materials and build new dwellings at a certain distance inland. Years and centuries passed; but the dunes and the ponds constantly advanced, and the inhabitants were again condemned to transport their villages into the midst of the heaths. These were foreseen misfortunes, and the chronicle preserves silence as to the successive emigrations; it confines itself to mentioning the names of some churches which were obliged to be abandoned to the sands and reconstructed far on the plateau of the Landes. Thus we know that the church of Lége was rebuilt in 1480 and in 1650, the first time at $2\frac{1}{8}$ miles, the second at nearly 2 miles further inland; but the halting-places of other local monuments of the same district are not known in an exact manner. As to the now

vanished towns of Lislan, Lélos, and many others, their ancient situation is unknown. After having lost its port and its hamlets, the township of Mimizan, formerly very important, was about to be entirely buried when, at the last moment, they succeeded in fixing the dunes by palisades and plantations. The semicircle of invading hills, like the serrated mouth of a crater, still seems to be on the point of devouring the houses.

Dunes have often been compared to gigantic sand-glasses measuring time by the progressive march of their sandy talus. The comparison is just, for the western winds, which effect all the changes on the coast-line of the Landes, obey at present the same laws as they did thousands of years ago, and very probably their force has not changed during that interval of time. The dunes, the ponds, and even the villages on the shores, may thus be considered as real geological chronometers; but, unfortunately, the indications that they furnish have not yet been deciphered with any certainty, and now that the dunes are fixed, it is too late to undertake this study. The illustrious Brémontier (whose book, printed in the year 1797, is still an authority on the question of moving sands) collected during eight years

Fig. 95.—Sable Island.



a series of observations which have given an average of from 22 to 27 yards for the annual progress of the dunes of La Teste. This result agrees in a remarkable manner with the indications furnished by the encroachments of the dunes of Lége during the last four hundred years. In admitting as normal the average calculated by Brémontier, one would arrive at this conclusion, that in the lapse of twenty centuries the dune would be able to invade the entire district of the Landes and cover the town of Bordeaux. A thousand years would even have sufficed to transform the fair plains of Bordelais into marshes, for the *étangs*, constantly driven back by the invading dunes, would have spread on the eastern side after having passed the culminating line of the plateau of the Landes. Researches undertaken in other places would have doubtless confirmed the observations made by Brémontier; but in the absence of these, we cannot accept measures taken at the foot of a group of isolated dunes as applying to the host of sands from Bayonne to the Point de Grave. In order to pronounce definitely, we must wait for observations which will not fail to be made one day, on the advance of the dunes in all those parts of the globe where these hillocks have not yet been arrested.

CHAPTER XXV.

OBSTACLES OPPOSED BY NATURE TO THE PROGRESS OF DUNES.—FIXATION OF THE SANDS BY SEEDS.

THE work of nature is, however, double; and if on one side she hastens the advance of the sands, on the other side she attempts to arrest them. She herself points out the means of prevention, or else prevents spontaneously the disasters of which she is the cause. In certain places, and especially on a part of the coasts of the Landes, she exercises a physical and chemical action by employing the oxide of iron which the water contains to consolidate the sands and transform them gradually into actual rocks. Elsewhere organic cements, composed of broken shells and remains of silicious and calcareous infusoria, agglutinate the arenaceous particles, and give them the necessary stability to resist the winds. But these means of consolidating the sands are exceptional. It is principally vegetation which fixes the moving hills on the sea-shore. On almost all coasts the sandy and calcareous débris of the soil contain enough fertilizing principles to nourish a certain number of hardy plants, which do not fear the salt air of the sea, and which send down their roots to a great depth, so as to absorb the necessary moisture. Among these hardy vegetables the commonest, and at the same time most useful, is Marramgrass (*Arundo arenaria*), whose slender and flexible stems can hardly arrest the wind, but whose strong roots, sometimes 12 or 15 yards long, develop all the better the less consistent is the sand. Various species of convolvuli creep over the ground, and fixing their vigorous cordage from place to place, sometimes envelop an entire dune in their network of leaves and flowers. Other plants rise more proudly, but if their stem is buried in the sands they transform it into a root, and give birth to a new shoot, which may be interred in its turn, without the plant being in danger of perishing. Thus such a seed germinating at the base of the dune often produces a plant which ends by spreading to the summit of the mountain, and fastens by a cable of roots the arenaceous strata which the creepers of the convolvulus fix on the surface. A number of plants, whose frail stems are half buried in the sand, are, perhaps, contemporary with the dune itself; perhaps even they existed before mankind had a history.

In this strife between the force of the winds and the power of vegetation, the definite issue depends at the same time on the climatological conditions, the nature of the soil, the form of the shore, and various other circumstances; among which we must rank, in the first place, the havoc caused by men and animals. In South America, on the shores of those tropical countries where the development of plants is favoured, according to the seasons, by an extreme heat and by torrents of

rain, and where the sands contain a considerable proportion of animal and vegetable remains, most of the dunes are already fixed at a few yards from the sea by mimosas, cactuses, and thorny trees. However, on the eastern shores of all the rivers of equatorial Brazil, which discharge themselves near the mouths of the Amazons, we see, even somewhat far from the sea, ranges of dunes from 25 to 50 feet in height, which move incessantly, driven by the breezes of the trade winds. This mobility of the sands is undoubtedly connected with the fact—established beyond question by Coutinho and Agassiz—that the shores are depressed in that part of Brazil, and, consequently, they incessantly change their form, so that the dunes have not yet had time to be fixed.

In Europe the flora of the sands is less rich than in equatorial countries. On the coasts of Jutland it is composed of only 234 species of plants, very insignificant for the most part, and the "white" dunes of the Danish peninsula, as well as those of Gascony and Holland, have also not enough cohesion to resist the furious western winds which assail them. It is probable, nevertheless, that even in the countries of the temperate zone the modest herbaceous vegetation of the sands of the coast could, after a certain lapse of centuries, acquire the strength necessary to fix the dunes, and prepare, by the slow accumulation of its remains, a vegetable bed, where large trees would grow spontaneously.

If it were not so, it would be difficult to understand how all the dunes of Europe were originally covered with forests. According to the unanimous testimony of the ancient geographers, the woods extended to the sea-shore in those plains which are now the Netherlands, and the Batavians, the Angles, and the Frisons had no special word in their idioms which designated a hillock of moving sand. Neither the great geographer Strabo, nor Pliny, the encyclopædist, nor any other writer of antiquity, mentions the existence of hills driven by the wind, though this phenomenon was certainly of a nature to strike them. Under a great many of the dunes of Gascony trunks of oak and pine-trees, with other substances, are discovered buried in the sand, above the ancient level of the Landes. Moreover, some dunes still bear magnificent woods, which can count at least several centuries of existence, and which probably were not planted by man. Not far from Arcachon one may wander in a forest where gigantic pines rise, unrivalled in France, and oaks 46 feet in circumference. Title-deeds of 1332 speak also of forests which covered the dunes of Medoc, and where the seigneurs of Lesparre went in merry company to chase the stag, the boar, or the roebuck. Montaigne, too, writing in the middle of the sixteenth century, says that invasions of the sand had taken place "for some time." Besides, why should the Landese, like the Spaniards, give the name of *mont* or *montagnes* to their forests, even those of the plains, if not because their hills of sand were, in former times, uniformly covered with trees?

Unhappily all those fine forests which once protected the low lands of the sea-coast against the invasion of the sands, were successively destroyed during the evil days of the Middle Ages, either by barbarian invaders, or by improvident lords, or by the peasants themselves. Even in the last century the King of Prussia, Frederick William I., being in great want of money, caused the forest of pines to be cut down, which extended without interruption over the dunes of the Frische Nehrung, from Dantzig to Pillau. The operation brought him the sum of 200,000 crowns, but the moving sands invaded the great inland bay, destroyed the fisheries, obstructed the navigable channel, buried the defending fortresses, and modified in the most disastrous manner the hydrographic economy of all those parts. In Holland and in Brittany this dismantling of the coast has produced still more fatal

results. On the borders of Lake Michigan, and at Cape Cod (Massachusetts) the clearing of the shore has also produced the formation of moving hills. But the inhabitants have only themselves to complain of ; the dunes are their work. A single imprudence may cause great misfortunes; and thus, according to Staring, one of the highest dunes of Friesland owes its origin to the destruction of a single oak.

It is for man now to arrest by his labour those hillocks of sand which he has, so to say, created by his imprudence. Happily this is not an impossible task. The shepherd of the French Landes, when he wishes to protect his cabin, erected in the depth of some ravine of the dunes, takes care to cut, in the lédes and surrounding marshes, grass or rushes, which he spreads over the soil in such a manner as to cover it completely, and to leave none exposed to the sea-breezes. This is sufficient; the sand remains immovable, and the dune is fixed for the future ; so long at least as no horse's foot, or the teeth of a sheep or wild animal, a shower of rain, or any other cause, have penetrated the protecting layer and restored their mobility to the sands. It is then necessary to carpet the ground with a new litter of plants.

This means of protection, which is moreover only practicable over small extents, is evidently quite provisional; to obtain a definite result we must have recourse to the direct fixation of the dunes by the seeds of trees or other plants, so as to present an insurmountable barrier to the winds. In modern times the Dutch, those great masters for all works concerning the sea and the coasts, have been the first to recognise the absolute necessity of arresting the dunes. Defended and menaced at the same time by those masses of moving sand which never cease to encroach on their territory, even while protecting it against the assaults of the sea, they have understood that the very safety of their country may depend on this rampart of hills, and for a century they have effectually consolidated it by planting reeds, maples, and firs.

The first attempts at the fixation of the dunes made in Gascony date from the beginning of the eighteenth century. M. de Ruhat, who had acquired the ancient Captalate de Buch, sowed some of the hills of La Teste with pine-trees; but though this plantation succeeded perfectly, the work was not continued, and everywhere else the indolent Landese allowed the dunes to advance to the assault of their villages. Later, the brothers Desbiey and the engineer Villers proposed repeatedly, at various times, the fixation of the entire district of sands. Their voices were not heard. It is to the celebrated Brémontier that the honour is due of first causing to be adopted and put in practice a complete plan for the culture of all the dunes. Inspired with the writings and example of his predecessors, and not disdaining to interrogate the herdsmen, who knew by tradition the means of arresting the sands, Brémontier first applied himself to the task in 1787. The works were interrupted in 1789, resumed in 1791, and completely abandoned again in 1793, in consequence of the opposition given by several of the inhabitants of La Teste. But important results had been already obtained. More than 620 acres of moving sands had been fixed in the environs of Arcachon; pines, oaks, and vines were in perfect growth, and the sowing of every two acres had not cost more than 200 francs. The possibility of arresting the advance of the dunes at little cost was perfectly demonstrated.

At the commencement of this century the interrupted work was resumed, and it was completed some years ago. The dunes of Gascony, fixed for the future, enrich the countries which they formerly threatened to bury, and in consequence

of the increasing value of the pines and their productions, we must reckon the annual increase of public wealth on the coast at hundreds of thousands of francs. The estimated present value of the forests of the Landese dunes is 25 millions; that is to say, 600 francs the acre. Thus, the means of safety applied by Brémontier has become a cause of prosperity to the inhabitants. At the same time, several happy results, which could not be looked for at first, have been obtained. The sand, protected from the rays of the sun by the shade of the pines, produces herbs, which are utilized as straw or food for cattle. The marshes, which during six months of the year were transformed by rain-water into impenetrable morasses, have been drained without the intervention of man, owing to the thousands of roots constantly pumping up the moisture from the sands. The surface of the vast ponds, situated at the eastern foot of the dunes, is lowered likewise to furnish the forest trees with the water necessary for their growth. Besides this, the fixation of the dunes has caused the "blouses" to disappear, in which men and animals were engulfed; the sands do not advance any farther, and the pools have ceased to exist. Science has repaired the disorders formerly caused by man's imprudence.

Part II.

THE ATMOSPHERE AND METEOROLOGY.

CHAPTER XXVI.

AIR THE AGENT OF THE VITAL CIRCULATION OF THE PLANET.—PHENOMENA OF REFLECTION AND REFRACTION.—MIRAGE.

DEATH and eternal silence would reign over all the earth if it were deprived of the atmosphere that envelops our planet. This gaseous, transparent, and invisible mass, which scarcely seems to form a part of the earth, is nevertheless its principal element. For it is the most mobile, and it is by its agency that life is sustained. The earth supports us, but whether men, animals, or plants, we alike require the air for our existence. Although not flying in it like birds, all living beings, whether they walk, climb, or fix their roots in the soil, are none the less children of the atmosphere.

Considered as one of the heavenly bodies, our planet is composed of a solid kernel surrounded by two fluid strata. The kernel is that which bears more especially the name of the earth; it is the rocky beds containing lava, molten metals, and the entire mass of unknown substances which occupies the centre of the globe. The sheet of water forming the seas and the network of rivers covers this solid skeleton, and above this watery envelope is stretched a second spherical layer still more fluid, and whose currents and counter-currents incessantly circulate from the pole to the equator, and from the equator to the pole, with the regularity of the lungs of man, by turns filled and exhausted. The atmosphere is truly the breath of the planet; like its satellite, which most astronomers tell us is destitute of a gaseous envelope, the earth would be only a dead star rolling in space if it suddenly lost the stratum of air that surrounds it and ceased to respire the regular breath of the winds.

The subtle and transparent air is composed of the same gases which are found in greater abundance in the opaque and solid crust of our globe. The four principal elements of all vegetable or animal organism, oxygen, nitrogen, hydrogen, and carbon, are found likewise in the atmosphere, the two first as constituent elements of the air, the third united with oxygen under the form of watery vapour, and the fourth mixed with the breath exhaled by animals, and with many other gases resulting from the decomposition of organic matter.

Between the action of nature and the eternal movement of the atmosphere, an exchange is constantly being effected, by which the gases, one instant in the animal, plant, or rock, fixed in an organism or in the terrestrial strata, are disengaged and recompose the atmosphere.

Animals and plants would soon be all destroyed, for want of necessary aliment, if the mixtures of vapours and gas were not effected by the incessant movement of the aërial masses. Men and animals would gradually kill themselves by absorbing again the carbonic acid already expelled from their lungs; and plants plunged in an atmosphere too full of oxygen emanating from their leaves would end too by dying. Happily, the currents of air, which pass in immense spirals over the surface of the earth, uniformly mix all the gases they carry away with them, and thus favour life over their whole course. To the temperate regions, which are principally the domain of man, they bring the oxygen which the immense forests of the tropical zone have exhaled; to these same forests they impart the carbon which is life to trees, and would be the death of man. Still more, they animate the globe itself, by carrying immense quantities of vapour to the mountains where the network of springs is elaborated, and in causing to circulate above the sea a dry air eager to absorb the water which evaporates from its surface. Like the heart in living organisms, the productive zone of the atmospheric currents occupies the central region in the ocean of air, and moves alternately to the north and south. It is thus that a movement of systole and diastole is produced in all the aërial mass, imparting the initiatory speed to the arterial currents which carry fertility to all points of the planet.

Every particle of gas passes thus continually from life to life, and escapes from death to death; by turns, wind, wave, earth, animal, or flower, despite its smallness, is the symbol of infinite motion. The air is an inexhaustible source whence all that lives draws its existence, an immense reservoir into which all that dies pours its last breath. Under the action of the atmosphere all the scattered organisms are born and perish. Life and death are equally in the air which we breathe, and perpetually succeed one another by the exchange of gaseous particles. The same elements which are exhaled from the leaves of the tree are carried by the wind to the infant that is just born; the last breath of a dying man goes to form the brilliant corolla of the flower, and compose its penetrating perfume. The breeze which gently caresses the stems of the plants is further on transformed into a tempest, uproots large trees, and destroys ships, with all their crews. It is thus, by an infinite series of minor catastrophes, that the atmosphere sustains the universal life of the globe.

Comparable to the ocean, as to the incessant circuit of its waves, the great atmospheric sea is not, however, enclosed in a basin bounded on all sides. The atmosphere travels without cessation, bearing away on its wings all the light objects which are exposed to its currents. It takes up the ashes from a crater in eruption, and lets them fall in places often hundreds of miles distant; it raises in its eddies myriads of animalculæ or clouds of pollen, which are wafted by it across seas to fall again in impalpable dust. It carries the sea itself in the form of clouds, and distributes it as rain and dews over the continents; it becomes highly charged with electricity, and discharges itself by the rays of the Aurora Borealis, or by vivid lightnings. It is the great vehicle by means of which is accomplished the universal interchange of the elements which compose the solid crust, the mass of waters, and of organic beings.

"The world is small!" said Columbus; but it is principally owing to the air,

which disregards distances, that the earth is diminished. Whatever be the number of yards or miles traversed by a seed, the point where it falls is not distant from the mother-plant. The northern coasts of the Mediterranean are brought nearer the great deserts of Africa, whose sands are transported by the *sirocco;* and in the same way we may say that the shores of Brazil, towards which the trade-winds blow, are contiguous to the distant archipelagos of the Azores and the Canaries. All those parts of the world united by atmospheric currents become thereby neighbours to each other; if not for the creatures who walk on the ground, at least for those which are carried by the movements of the air. By the incessant mixture of the aërial masses all the regions of the solid kernel of the earth are brought nearer, contrasts are blended, and harmony is established between the productions and the climates, no less than in the general aspect of nature.

The winds are also powerful geological agents. Thus the aërial currents of certain latitudes transport clouds of dust, which may at length render vast countries sterile or fertile, either by covering the natural soil with an unfruitful layer, or by effecting a happy mixture with it. On the banks of the Nile, the sand of the desert which the wind mingles with the thick mud of the river, contributes to develop the marvellous productive force of the land, while in the neighbouring plains, which are destitute of moisture, it buries the plants and renders the soil wholly unfit for vegetation. Elsewhere, and principally on the low coasts of the sea, the wind drives hills of sand across the plains, barring the outlets of the streams, and gradually driving the water up the slope of the continent.

In certain places the aërial current even goes so far as to temporarily change the level of the sea; it sometimes arrests the waves, or hurls them against the shores, and alternately dries up the bed, and causes disastrous inundations. Sometimes the wind, which descends with violence from the polar regions of North America to the Gulf of Mexico, keeps back three or even four successive tides. Then these, returning altogether in one foaming mass, sweep over whole islands off the low coasts of Louisiana and Texas. In the same way when the *pampero*, or south-west wind, blows over the great estuary of La Plata, its waters are sometimes lowered by 12 or even 18 feet in less than half a day, and the vessels that were floating in the road remain stranded in the mud.

This is not all. The wind can also modify the configuration of the shores, since the waves of the sea, which contribute so largely towards the sculpturing of them, receive from it their impulsive force. Thus the large arm of the Rhone perhaps owes its south-easterly direction to the *mistral* which descends from the Cevennes.

As to the delta of the Mississippi, its exterior contours are probably modelled by the south-east monsoon which prevails in that country; the southern passage, which opens exactly in the direction of the prevailing wind, is almost entirely obstructed by the dike of mud that the surf has raised across its current. The two arms of the Mississippi which carry the greatest quantity of water are directed, the one to the south-west, the other to the north-east; that is to say, each of them forms a right angle with the monsoon from the south-east. It is the aërial current which has forced the long peninsulas of the Mississippi to spread thus over the waters like the branches of a great fallen tree.

The geological labours of the winds are, however, accomplished, for the most part, in an indirect manner, either by the evaporation of the moisture of the continents, or by causing considerable downfalls of rain. During the course of ages the contours of the land and sea have not ceased to change, and, in consequence of

these gradual modifications, the winds themselves have been subjected to analogous variations. Some are saturated with the vapour of water, and the clouds that they carry are deposited in rivers and lakes in the midst of land. Other atmospheric currents have lost their moisture in great part, and then in passing over inland seas they have absorbed them; pumped them, so to speak, leaving behind them smiling plains transformed into deserts. Without any doubt it is the winds which have now dried the lands of Cape Natal and Transvaal; it is they that have been the great agents in the work of drying up central Asia; they have drunk the vast extent of water that formerly stretched from the Euxine to the Caspian Sea, and from the Lake of Aral to the Gulf of Obi, and left steppes of salt in the place of this ancient Mediterranean.

It is by means of the atmosphere, too, that the exchange of particles between the earth and bodies wandering in space is accomplished. When an aërolite, shot like an enormous bullet through space, meets the exterior strata of gas that surround the earth, it is instantly set on fire, and bursts either entirely or on the surface; and hurling with violence some fragments to the ground, it leaves behind it a long train of luminous matter resembling a fiery track. Owing to the resistance opposed by the atmosphere to the passage of the strange star, the globe is every year enriched in thi smanner with material brought from the sky.

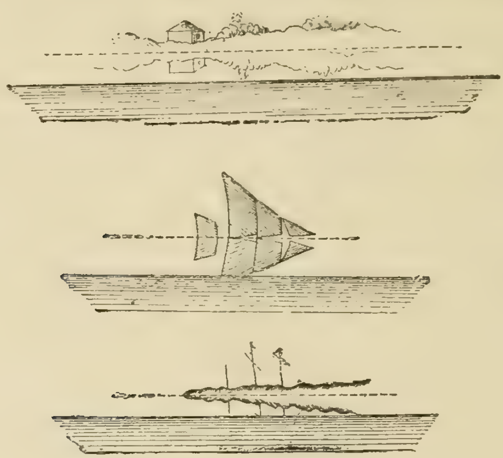
The strata of air, moreover, are the vehicle of all sounds; they also convey the vibrations of light and heat. Deprived of this envelope, the globe would immediately be wrapt in complete darkness. But if the atmosphere allows the rays of luminous heat emitted by the sun to pass, it intercepts in return a great part of the dark rays which escape from the earth into space. It is thus that the globe has been able to preserve its normal temperature, and has become the theatre of life.

The atmosphere, which as the common vehicle of exchange is ever in motion, is also the great agent by which nature receives the wonderful colours that beautify her. It is owing to the reflection of the blue rays that the sky and the distant heights of the horizon assume that beautiful azure hue, which varies with the altitude of each region, the abundance of watery vapour, and the contrast of the clouds. It is owing to the refraction undergone by the luminous rays in passing obliquely through the aërial strata, that the sun is announced every morning by the vague glimmers of twilight, then by the splendours of dawn, and thus shows himself before the astronomical hour of his rising. It is also due to an analogous phenomenon that in the evening he seems to slacken his descent below the horizon, and even after he has disappeared colours the west for a long time with the purple of sunset. Without the gaseous envelope of the earth we should never see those varied plays of light, those changing harmonies of colour, those gradual transformations of delicate shades, which form the marvellous beauty of our mornings and evenings. The special works on meteorology describe at length all these brilliant phenomena of the air, the rainbows, halos, parhelions, and that splendid spectacle of the "after-glow" which colours the snow and ice of the Alps with a rosy tint more than twenty minutes after the sun has set. Nothing is so beautiful as this phenomenon, due to the contrast of the lower slopes which are already in the shade, and the high peaks which the solar rays reflected above the horizon still illuminate. When the Aiguille-Verte is already veiled in shadow, as well as the neighbouring summits of Mont Blanc, the latter is truly transfigured by the light glittering on its snows. "We might think we then saw a form foreign to the earth;" then all at once the flame is extinguished, the colours so brilliant vanish, "to give

place to an aspect that we may truly call cadaverous, for nothing approaches more nearly to the contrast between life and death on the human face than this passing from the light of day to the shadow of night on the high mountains."

The *mirage* is another singular optical effect, due to the deviation of the rays of light which traverse the atmosphere. When the surface of the earth is much heated by the sun, the lower strata of air expand and often become lighter than the strata situated above. If the air is agitated by the wind it then rises, oscillating like the smoke that rises from a high furnace, and the outlines of all objects seen through this vapour seem to tremble; if a calm reigns in the atmosphere all the objects bathed by the denser strata are reflected, as in a sheet of water, in the more expanded air, and all their images appear double; hence the name of *espeio* (mirror) which the inhabitants of South America give to the mirage. In the midst of the arid desert, at hundreds of miles from any stream, bushes and rocks are reflected in the air as in the basin of a fountain; on the sea the ships, the shores, and signals are reproduced as on a second ocean; even in the large squares

Fig. 96.—Mirages at Verdon, at the Mouth of the Gironde.

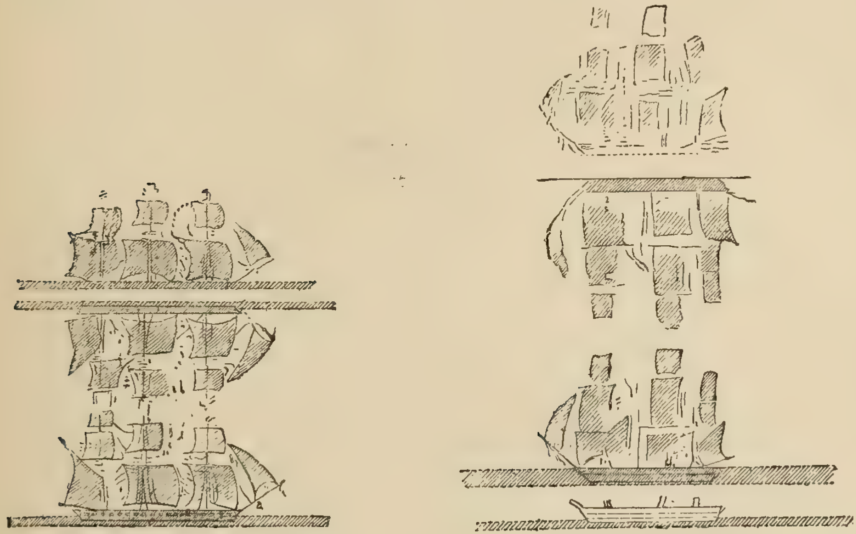


of our cities which a burning sun strikes, the statues sometimes seem to bathe their feet in a crystalline water reflecting their graceful forms. The optical illusion which thus paints imaginary objects even in our cities, is the "Fata Morgana" of Italy, the deceptive "Delibab" of the Magyar puszta, and the "Thirst of the gazelle" on the plains of Hindostan. It shows from afar fresh oases and rippling waters to the fatigued travellers, who, where the deceitful picture glitters, only find aridity, thirst, and perhaps death. In the deserts of Arabia the plain seems every day transformed into an immense lake. In proportion as the sun sinks the magic sheet retires, then it fades completely away, to reappear the next day an hour or two before noon.

The phenomenon of reflection is almost always accompanied by lateral movements which apparently alter the position of objects, in the same way as do plates of glass of unequal thickness; we then see large masses of different forms detaching themselves to the right and left of the distant objects, and floating fantastically in the air. These phenomena of mirage are most curious in the polar seas, already strewn with blocks and icebergs of every variety of contour. The surface of the ocean bristles with points, needles, crests, and overhanging cornices, which separate,

rejoin each other, and then vanish, to reappear again. Nowhere do we see more astonishing phantasmagoria. As to the prodigious scenes that the mirage is said to present to the eyes of the traveller, by showing him forests of palm-trees, temples with colonnades, caravans, armies on the march, and people gathered for fêtes, they

Fig. 97.—Mirages of the "Vincennes" and of the "Peacock," after Wilkes



are probably in great part produced by fever under the ardent sun, for in this fiery atmosphere which floats above the whitened plains and reflects the splendour and the heat, the head is burning, the imagination excited, and the eye sees no longer anything but the forms of fancy.

CHAPTER XXVII.

WEIGHT OF THE AIR.—HEIGHT OF THE UPPER STRATA.—BAROMETRIC MEASURES.

THE weight of the aërial particles, which makes itself felt in so terrible a manner in hurricanes, is relatively very small, since a litre of air (nine-tenths of a quart) taken at the surface of the ground, and at the temperature of zero, weighs 770 times less than a litre of water. But the atmospheric mass surrounding the globe is such that if it were to be entirely agglomerated in a single ball, it would weigh as much as a sphere of copper nearly 63 miles in diameter; that is, the twelve hundred thousandth part of the mass of the earth. The pressure exercised by the atmosphere on a man of middle size is not less than 14 or 15 tons; it is true, however, that this pressure making itself felt at the same time in all directions on our frame, is by that very fact neutralized. We know that a column of air on any point whatever of the earth is equivalent on an average to that of a column of water of 32 feet, or to 30 inches of mercury; it is the knowledge of this fact that has enabled us to construct the barometer.

Still, if we know the weight of the atmosphere we cannot yet say in a positive manner to what distance it rises in space. If the higher aërial strata had the same density as those on the surface of the sea, the total thickness of the air would not exceed 5 miles, and consequently, the highest mountains of the earth, the Gaourisankar, the Kinchinjunga, the Dapsang, and many others, would raise their peaks into empty space above the atmosphere. But it is not so; above the lower strata, compressed by the weight of all the superincumbent aërial mass, the particles separate in proportion as the pressure diminishes; the air becomes rarer and rarer in the heights of space, and ends by being completely lost, like the thin fluid which composes the tail of comets. According to the calculations of Laplace, it is at more than 26000 miles above the surface of the earth that, in consequence of the increase of centrifugal force, and the diminution of the weight, the aërial particles which may still be in space must forcibly escape from the terrestrial orbit. Perhaps it is, in fact, in these elevated regions, at the very limits of the spheres of attraction of the heavenly bodies, that the exchange of their gaseous particles takes place. However that may be, it is at a height very inconsiderable in comparison with the extreme limit indicated by Laplace, that the atmosphere ceases to be respirable by man. At the summit of Etna—that is to say, at an elevation of two miles—we have nearly a third of the aërial mass under our feet. At $3\frac{1}{2}$ miles, a height above which a great many mountains raise their peaks, the column of air which rests on the ground has already lost one half of its weight; consequently,

all the gaseous mass which extends far into the sky to immeasurable distances, is simply equal to the aërial strata compressed into this lower region.

More than two hundred years ago, Perier, following the indications of his brother-in-law, Pascal, established by the first direct experiment the diminution of the weight of the air in a vertical direction; he ascended Puy-de-Dôme, with the barometer in his hand, and during the ascent the column of mercury which measured the atmospheric pressure never ceased to sink gradually in the tube, and thus the means of measuring the height of mountains above the level of the sea, by simply reading the barometrical indications, was discovered. Since this epoch science has made great progress, the precise law of the decrease of the weight of the air and all other elastic gases has been brought to light by Mariotte; and innumerable travellers have been able, with the aid of the barometer, to indicate approximately the altitude of the salient points in the various countries that they have traversed. Nevertheless, one can never be sure that the barometer has furnished perfectly exact measures of height. In each barometric reading we must take into account the temperature, the quantity of watery vapour contained in the atmosphere, the agitation of the winds—in a word, all those physical conditions of the air whose weight we are about to measure, as each of these secondary observations makes a greater or less correction necessary in the final result. The direct results obtained by trigonometry are at present the only ones that give in an exact manner the height of the surface.

To ascertain the altitude of summits another means is also employed, which, in consequence of the defectiveness of the instruments, generally gives results still less exact than those of the barometer. This means consists in measuring the heat of boiling water. In fact, the boiling point, or the temperature at which the tension of the vapour of water exactly balances the atmospheric pressure, must necessarily sink in proportion as the pressure diminishes. It has been calculated that the average fall of boiling point is 18° F. for every 1062 feet of vertical height. But experiments may give for the heights of mountains differences of many hundred feet. Thus, Tyndall found in August, 1859, that the temperature of boiling water on the summit of Mont Blanc was 84·97°, while in the preceding year he had observed a slightly lower boiling point on Mont Rosa, though this latter peak is 558 feet lower than the giant of the Alps.

To what height is the air dense enough for a man to be able to find the oxygen necessary for his lungs, and to live there for a few seconds at least? The climbers of mountains have never reached this extreme limit, because of the fatigues of the ascent, which add to their difficulty of finding a sufficient quantity of air. Thus the highest peaks of the Himalayas and the Andes have remained to this day untrodden by human foot. At the summit of Ibi-Gamin, the highest point reached before Graham's recent ascent, Robert Schlagintweit found himself at an elevation of 4¼ miles. The barometer was only 13·3 inches, so that the traveller had beneath him nearly three-fifths of the mass of air.

Nevertheless, thanks to the balloon, aeronauts have been able to ascend to heights which even the condor does not reach, and from whence the highest mountains would appear as if they rose from the depth of an abyss. In 1804, Gay Lussac ascended to 4½ miles; in 1851, Barral and Bixio ascended a little higher; in 1858, Rush and Green rose to 5 miles. But these are all altitudes inferior to the highest summits of the continents. Finally, on September 5, 1862, Glaisher and Coxwell undertook an aeronautic expedition, in which they resolved to ascend as long as they could preserve the sense of their own existence. The air becoming

too rare for their lungs, hardly allowed them to pant; they had palpitations of the heart, singing in the ears; the blood swelled the arteries of their temples, their fingers froze and refused to move; but their will sustained them, they threw more sand from the car, and thus gave themselves a new impetus into the atmosphere. Glaisher fainted away, but his companion did nothing to arrest the ascent; his eyes fixed on the instruments, he noted with a glance the gradual sinking of the column of mercury in the barometer and thermometer, as if he were in the observatory at Kew. Gradually taken possession of by torpor, the aeronaut lost the use of his hands; but he still held the cord of the valve between his teeth, and when he felt that but one single second separated him and his friend from death, then he let the gas escape, and the balloon was arrested and descended gradually towards the plains situated at $6\frac{1}{2}$, or perhaps at $6\frac{3}{4}$, miles below, for the column of the barometer was only at 6·5 inches. What noble courage on the part of these men risking death with such simplicity of soul, and for the sole advantage of studying the temperature of an atmosphere where neither man nor bird can live! Certainly, it would greatly lower the force of soul and philosophical calm to compare it to the brutal courage of the soldier rushing into the thickest of the fray intoxicated with powder, din, and blood!

At the height to which Glaisher and Coxwell rose, they had nearly four-fifths of the weight of the atmospheric strata beneath them; the remaining fifth, where the air is too rarefied for the lungs of man, rises dilated more and more to unknown heights. We can, however, ascertain the presence of the aërial fluid much above the space to which man has been able to ascend. In truth, the refraction of the solar rays in the dawn and twilight has permitted us long ago to calculate that the appreciable part of the atmosphere rises to, at least, 45 miles, and owing to the perfection of optical instruments, the visible limits of this ocean of air, which bathes our globe, have gradually retreated. In supporting the observations made in tropical regions on the phenomena of the twilight, M. Emmanuel Liais believed he could affirm that the height is in reality 200 and even 210 miles.

By this the real diameter of the earth would be increased by about a tenth. Though this atmospheric stratum is usually left out of the calculations of astronomers on the dimensions of the planet, it ought nevertheless to be measured as an integral part of the earth.

CHAPTER XXVIII.

MEAN PRESSURE OF THE ATMOSPHERE UNDER VARIOUS LATITUDES.—DENSITY OF THE AIR IN THE NORTHERN HEMISPHERE.—DIURNAL OSCILLATIONS OF THE BAROMETRICAL COLUMN.—ANNUAL OSCILLATIONS.—IRREGULAR VARIATIONS.—ISO-BAROMETRIC LINES.

THE atmosphere is of such mobility that its weight, measured in an exact manner by the column of mercury in the barometer, varies incessantly all over the earth. The various meteoric changes, from cold to heat, from dryness to moisture, augment or diminish the pressure of the air, and in consequence a corresponding oscillation is produced in the mercury contained within the tube of the instrument. Now, any volume of mercury being about 10500 times heavier than the same volume of air taken at the level of the ocean, we must conclude from this that every movement of the barometric column reveals a change 10500 times greater in aërial space.

When air is heated either by the direct influence of the sun or by a current of higher temperature, its particles expand, become relatively lighter, ascend into space, and then spread out laterally. The pressure then diminishes, and in consequence the column of mercury in the barometer must fall. The contrary takes place when the air is condensed by cold, and when the aërial masses flow together to fill up the space; the weight of the atmosphere is increased, and the level of the mercury rises in the instrument. This is the reason why the fall of the barometer indicates generally an increase of temperature, while a diminution of heat is marked by the contrary phenomenon. The barometer and thermometer oscillate in inverse ways. It is true that the air can absorb so much the more watery vapour the warmer it is, and in this way the pressure which is diminished on one side by the ascent, and the lateral flow of the aërial fluid, is augmented on the other by the increase of vapour contained in the atmosphere; air becoming colder, on the other hand, loses its capacity of dissolving the watery vapour, and grows lighter in proportion. Thus the phenomena counterbalance each other, and it is not without numerous observations treated with sagacity that we are able to distinguish that which, in slight barometric oscillations, ought to be attributed either to the pressure of the pure air, or to that of the watery vapour. As to the abrupt variations in respect to which we cannot be mistaken, they are sometimes enormous; there are even some which are marked in the column of mercury by a difference of 2 or 3 inches, one-fifteenth of the total height. A tempest in the ocean of the air is the cause of this agitation of the liquid in the instrument.

The pressure of the atmosphere varies over all the earth, and we cannot yet

indicate it with exactitude for the entire globe. It is probable, however, that at the surface of the sea it exceeds on an average, by a slight fraction, the amount of 29·90 inches. Towards the equator the ordinary pressure is only 29·84 inches; but from the 10th degree of latitude in the two hemispheres the pressure increases little by little, and towards the 30th or 35th degree it attains its maximum, 30 or 30·08 inches. From thence, in the direction of the poles, the pressure diminishes; towards the 50th degree it is 29·92 inches, and further north 29·76 inches only. Thus it is at about an equal distance between the pole and the equator that the air exercises on an average its greatest pressure on the barometric column; nevertheless, there being much more watery vapour in the aërial strata of the temperate zone than in those of the polar zone, it is probable that, the air being perfectly dry, its pressure would continually increase from the equator to the poles more or less regularly in proportion to the sinking of the temperature. This is moreover a phenomenon rendered very probable by the rise in the barometer, which is ordinarily produced by the transition from heat to cold. However it may be, the researches of Sir James Ross and Wilkes in the southern seas establish the fact that on an average the barometer is slightly higher in the northern than in the southern hemisphere. We must necessarily conclude from this, that a greater quantity of air is accumulated over that half of the earth where the continents are grouped. Thus, as Sir John Herschel remarks, the current of a river is always rippled above an unequal and stony bed; and in the same way the atmosphere must swell in waves above the continental masses This best explains the astonishing contrast between the two hemispheres.

The observations of Rikachov, made in various regions of Central Asia and North Europe, have revealed very considerable oscillations in atmospheric pressure, of which meteorologists had previously no idea. Thus, while the mean height of the mercury east of the Caspian Sea should not be more than about 763 or 764 millimètres, it rises in winter to 770 and even 780 millimètres. Rikachov records even a far greater extreme, that of 796·4 millimètres, observed by him at Nerchinskiy Zavod, in South Siberia, on January 17, 1869. This barometric pressure, however, was obtained by calculating as at sea level the position of Nerchinskiy Zavod, which really stands at an altitude of 2280 feet. But in the same region the barometric column is said to have risen to 880 millimètres during the winter of 1876.

By a remarkable phenomenon of compensation, the enormous atmospheric wave sweeping over Northern Asia in winter, and representing a supplementary weight of over 250000 tons to the square mile, is limited westwards by the very deepest aërial depression, as it may be called, on the surface of the globe.

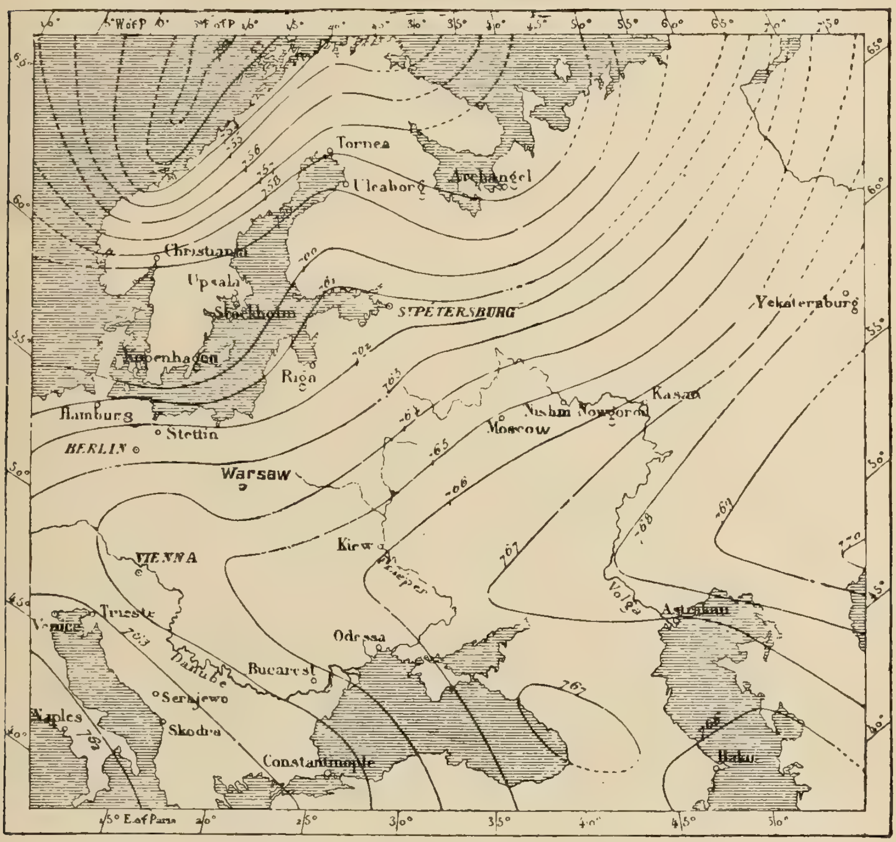
On the west Scandinavian seaboard the atmosphere in winter has a mean barometric height of 753 millimètres, and at Reykjavik, in Iceland, the barometer has been known to fall in quite exceptional cases as low as 691 millimètres. Hence at sea-level the absolute divergence of the mercurial column may exceed 4 inches.

In summer the inverse phenomenon takes place, the barometrical mean for Siberia being 754 millimètres, and for Scandinavia 762 during this season. Without taking into account the really prodigious extremes recorded by Rikachov, the yearly oscillation of the mercurial column may be estimated at 17 millimètres for the regions of Central Asia. To what causes are to be attributed these great extremes? Further research may enable the meteorologist to answer this question. Meantime it is already known that the atmospheric moisture diffused in summer

over the Scandinavian coast-lands must diminish the normal pressure, while the great stillness of the dry air accumulated on Central Asia must on the contrary increase to a considerable degree the summer barometric pressure throughout that region.

Phenomena of a similar order, but on a less important scale, take place in every part of the world. But the essential fact in the movement of the aërial currents is a general equipoise of the atmospheric volume between the two hemispheres according to the alternations of the seasons. During the summer of the continental or northern hemisphere the barometric pressure is lowered, to be again raised in winter, when it attains its greatest elevation. In the same way the pressures are

Fig. 98.—Winter Isobars in Russia.



The numbers indicate the barometric heights.
Scale 1 : 26,000,000.
100 500 1000 K

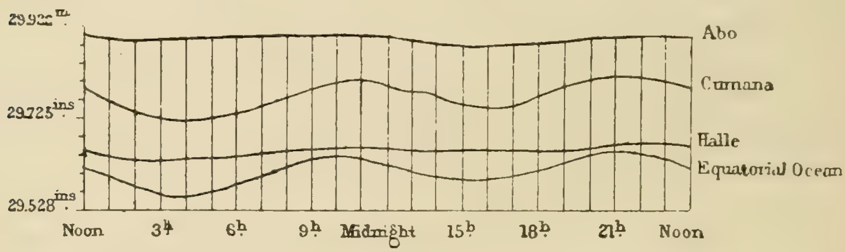
lowered throughout the summer months in the oceanic or southern hemisphere. Thus the atmosphere is balanced during the year from pole to pole, and on these two great fundamental waves are superimposed all the secondary waves associated with stormy and fine weather.

If the normal pressure of the atmospheric strata varies at the level of the ocean under different latitudes, it varies also all over the earth according to the hours and seasons; it obeys the rhythm of time as well as that of space. Every day the aërial mass oscillates twice in inverse directions. In the morning towards four o'clock the barometric column presents a first minimum of height, but it rises gradually, and towards ten o'clock in the morning it attains its highest elevation;

afterwards the pressure of the air diminishes till towards four o'clock in the evening, the time when the barometer is at its minimum of height. The column of mercury then begins to rise till ten o'clock at night, to sink again for six hours. The periods of the day during which these changes occur are known under the name of "tropical hours." The curve of variations, as we see by the accompanying figure, is much more regular in the equatorial than in the temperate zone.

What is the cause of this double daily oscillation? Many meteorologists formerly recognised in these movements of the barometer regular tides, similar to those in the ocean, and, like them, obeying the combined influences of the sun and moon. But these oscillations always occur, on an average, at the same hours, and do not present at the epoch of syzygies and quadratures phenomena corresponding to those of the ebb and flow. The researches of Aimé, of Flangergues, and other natural philosophers have, it is true, established the existence of an aërial tide; but the amplitude of this movement is very slight in comparison with that which occurs between the tropical hours. It is, therefore, by the combined influence of the heat of the day, and the pressure of watery vapour, that we must explain, with Dove, the two movements of rising and falling which take place every day in the column of mercury. Commencing in the cold hours of the morning, the gradual increase of temperature must result in expanding the atmosphere, and making the

Fig. 99.—Tropical Hours of the Equatorial Ocean of Cumana, of Halle, and Abo.



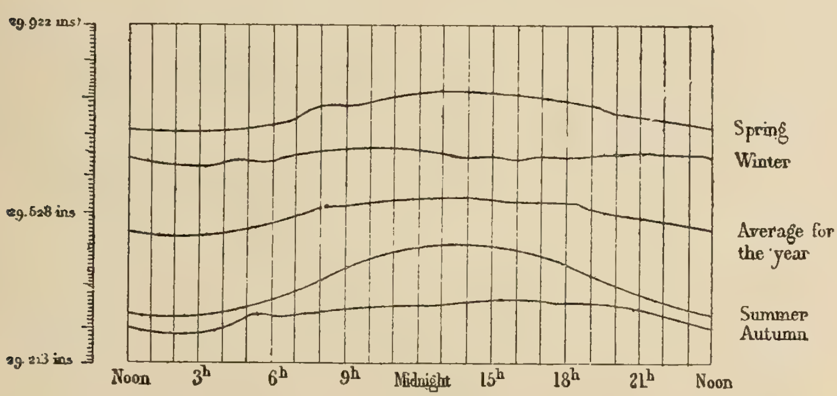
barometer sink. But while the pressure of the air diminishes, the quantity of watery vapour augments rapidly, and its pressure added to that of the air, produces a sort of temporary wave, after which the barometric column continues to fall, to rise again with the nocturnal cold. If the pressure of the watery vapour disappeared from the atmosphere the barometer would rise regularly in all seasons towards the middle of the night, and would be at its lowest towards the middle of the day. This is shown by the following figure, representing the barometric oscillation of the dry air at the port of Apenrade, on an estuary of the Baltic. In very dry countries, such as Eastern Siberia, the pressure of the watery vapour is too slight to counterbalance the action of temperature, and in consequence only two oscillations occur during the four-and-twenty hours, a fall with the increase of temperature, and a rise with the cold of night.

The American Eclipse Expedition to the Caroline Islands in May, 1883, also made exceedingly interesting meteorological observations, of which the most important are those on the pressure of the air, as they elucidate some points in the daily period of this phenomenon ("Memoirs of the National Academy of Sciences," vol. ii.). As this is very regular in the tropics, any difference in it points to exceedingly potent influences, and it is easy to surmise that, in the daytime, none, except a cyclone, can be more potent than an eclipse, as no other can shade the whole extent of the atmosphere. The result was an accelerated diminution of

pressure from 10·15 to 11·30 a.m. (totality 11·32 to 11·37 a.m.), then a rise to about noon—*i.e.* at a time when there is generally a great fall—and later again an accelerated fall. The explanation is probably the following: the accelerated fall at the beginning is caused by the diminished temperature and elasticity of the air. Then, as the height of equal pressure diminished in the shaded area, air began to flow in from the vicinity, causing a rise of pressure, and the subsequent rapid fall was a return to the normal condition.

The diurnal movements of the barometer are much more regular and more easily ascertained in the equatorial regions and near the level of the sea than under high latitudes and in the interior of continents. This is because over the tropical seas the alternations of temperature, evaporation, and precipitation succeed each other, like all other physical phenomena, with greater regularity than in other parts of the globe. Besides, it was in the equatorial seas that the diurnal oscillation was observed for the first time, and it was in these same latitudes that Humboldt was able to ascertain the hours exactly. In the temperate regions these regular movements of the barometric column are in a great measure hidden by the abrupt leaps of the mercury, obeying the constant variations of the atmosphere; it is. therefore,

Fig. 100.—Pressure of Dry Air at Apenrade.

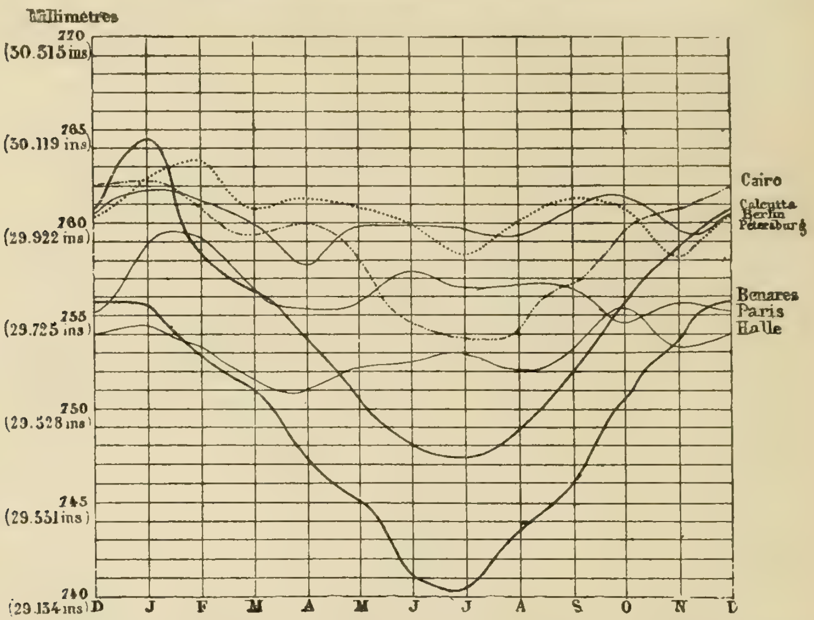


only after a longer or shorter series of days, or even weeks, that meteorologists can, by establishing averages, reveal normal oscillations analogous to those which occur at the equator. In the high mountain regions it is still more difficult to ascertain the regular succession of the barometric waves, for the changes which occur in the lower strata of the air are only felt later, and are variously mixed in the higher strata. Thus the rising of the barometer which takes place towards ten in the morning at Zurich, does not occur on the summit of the Righi till two o'clock in the afternoon, and only at three o'clock on the Faulhorn; often the depression of the barometric column does not even make itself felt in the afternoon on these heights, and each day presents but a single great oscillation.

The annual variations of the pressure of the air present alternations analogous to those of the diurnal variations. In the tropical countries, where the seasons follow one another with great regularity, and in the interior of continents, the air of which contains but a slight quantity of watery vapour, the mercury of the barometer gradually sinks from winter to summer in inverse proportion to the heat, and re-ascends with the cold from summer to winter. At Calcutta, at Benares, in Hindostan, as at St. Petersburg, in Prussia, and at Nertschinsk, in Siberia, the maxi-

mum of the pressure of the air is perceptible in the month of January, while the minimum occurs in the month of July. The atmosphere is now heavier, now lighter in each hemisphere according to the regular alternations of heat and cold. Thus, as shown by figure 100, the annual variation in the pressure of the air occurs in the same manner in all the countries situated on the same side of the equator; but the phenomenon is much more striking in tropical climates than under high latitudes. In the greater part of the countries of the temperate zone, and above all on the shores of the ocean, the pressure of the watery vapour during the summer increases considerably, and thus, counterbalancing the normal effect of dry air, gives to the barometric curve a maximum of summer which corresponds to the diurnal rise of ten o'clock in the morning, or else complicates the series of monthly variations by very numerous irregularities. Each one of these inflexions corresponds to some

Fig. 101.—Monthly Variations in the Pressure of the Atmosphere at Cairo, Calcutta, Berlin, St. Petersburg, Benares, Paris, and Halle.



important phenomenon in local climate, cold or heat, storms, or tranquillity of the air, dryness, or a great quantity of watery vapour. In general it is at the epoch of the equinoxes, when the temperature is nearly equal to the annual mean, that the mean barometric pressure of the year is established.

As to the irregular variations, they are also accomplished according to a certain rhythm in various regions of the globe. At the equator they are almost nothing, but in proportion as we approach either of the poles, the irregularities become more marked, and the leaps produced in the column of mercury by sudden changes of temperature, and by the alternations of winds and storms, succeed each other more frequently. In tropical regions these differences of barometric height are hardly a few fractions of an inch, while in the temperate latitudes they have exceeded 2·1 inches at Milan for a period of eighty-one years, and 26 inches at St. Petersburg for a period of nineteen years. In order to obtain figures more comparable with each other, Kämtz has calculated the monthly amount of the oscillations of the

barometer for every station, and in this way has been able to draw up the following table :—

Latitude.	Monthly Barometric Amplitude.
0° to 10°	0·1 inches.
10° to 20°	0·17 ,,
20° to 30°	0·32 ,,
30° to 40°	0·53 ,,
40° to 50°	0·81 ,,
50° to 60°	1·03 ,,
60° to 70°	1·2 ,,

Still, we must not expect to find exactly the same amplitude per month at all the points situated at the same distance from the equator. In this respect, on the contrary, we observe great diversities, which we must attribute to the difference of continental forms and of climates. By uniting with each other all the points in which the same monthly variation in the pressure of the air occurs, we obtain a series of lines called *iso-barometric*, which all curve to the north across the Atlantic, and on the whole much resemble the lines called *isothermal.* These are curves imagined by Kämtz, which indicate the true latitude for the general movements of the atmosphere. In spite of the extreme mobility of air, in spite of the tempests which roll with fury from one point to another of the horizon and disturb for a moment the regularity of atmospherical phenomena, these lines maintain from year to year their mean direction; while indicating the disturbances of the air, they show by their permanence and their regularity how much these commotions depend on the great laws which rule our planet.

CHAPTER XXIX.

GENERAL LAW OF THE CIRCULATION OF WINDS.—TRADE-WINDS FROM THE NORTH-EAST AND SOUTH-EAST.—EQUATORIAL CALMS.—OSCILLATION OF THE SYSTEM OF WINDS.—THE DOLDRUMS.

IN the continental regions, and principally in those of the temperate zone, it would often be difficult to recognize at first the general law which presides over the movements of the atmosphere, for these various oscillations may be modified by a crowd of local circumstances, such as the direction and height of mountain-chains, the extent of plains, the contours of the shores, the abundance or scarcity of vegetation. Even in one day the winds will sometimes blow successively from all points of space, and among these rapid changes to which the atmospheric currents are subject it is not always possible to ascertain with certainty the normal direction of the mass of air in movement. The lower currents are often very thin, so that the aeronaut rising into space may sometimes rapidly pass through several strata all setting in different directions. Green, who has made no less than 426 ascensions, always met at a certain height a westerly breeze, whatever might be the direction of the lower currents. To understand the laws of the atmosphere in their simplicity we must transport ourselves to the equatorial regions of the ocean, above which the sun describes each day its immense semicircle in the space of twelve hours, and where all the movements of nature, regulated by the uniform march of the sun, have something of the rhythm of the celestial cycles. It is there that we may seek the first displacement of the atmosphere, which travels as an immense sheet of air all round the globe. We are there present at the birth of the winds. It is there that Eolus would be seated if the gods still lived.

During the days of summer we perceive from afar a vibratory motion of the air over the heated earth, a kind of vaporous trembling, doubtless rendered visible by the incessantly changing mirage of objects lying beyond. This is because the strata of the atmosphere reposing on the ground have gradually expanded, and rise in spirals through the colder and denser medium which weighs upon them. In the same way the rarefied air of furnaces mounts rapidly towards the upper regions, whither its relative lightness carries it.

A similar movement is produced on a very large scale in the equatorial regions. The great force of the sun's rays making themselves principally felt in these countries of the world, aërial strata expand under the influence of the heat much more than in other latitudes. They become lighter, and rise rapidly into space, as is shown by the slight pressure of the air on the barometric column. Thus a void is formed, which the adjacent masses of air hasten to fill, and two horizontal currents

go to feed the great vertical current which ascends towards the higher strata of air in the equatorial regions. But these horizontal currents themselves leave spaces behind them towards which new masses of air rush ; the atmospheric waves move nearer and nearer through all the zones as far as the polar ice, and from the two ends of the planet, they march towards the equator, where the ascending movement of the overheated air summons them. Two winds, the one from the north, the other from the south, take their origin from the midst of the ice of the two opposite poles to meet at the equatorial circle.

If the earth were not carried by a movement of rotation around its axis, the atmospheric current would flow directly towards the equator, without deviating to the right or left from the lines of the meridian. The northern current would flow in a straight line to the south, the southern current would direct itself exactly towards the north, and they would meet in direct opposition in the equatorial regions. But it does not happen thus, because of the rotation of the globe from west to east. The speed of this movement varies for each point of the terrestrial surface, as the diameter of its latitude ; whilst it is nothing at the poles, it is 520 miles per hour at the 60th degree of latitude, north or south ; at the equator itself it is 1050 miles. The mass of air which flows from the poles towards the tropical zone thus travels successively over latitudes whose own speed around the axis of the globe is greater than theirs ; consequently they are compelled to deviate further and further towards the west in the opposite direction from the general movement of the earth. Instead of being directed perpendicularly towards the equator, to form with it an angle of 90 degrees, the aërial currents coming from the poles strike the equinoctial line obliquely at an acute angle. Thus the same planetary phenomenon that causes the deviation of the flow of water of the oceanic currents, and perhaps even, according to M. Musset, the swelling of the trunks of trees in the direction from east to west, suffices likewise to put in motion the whole mass of the atmosphere. The rivers of the air reproduce, only in greater proportions, on account of their larger domain, the immense curves of the oceanic currents. The two fluids in movement, winds and marine currents, are superposed in their march around the planet.

In the tropical zone, where the incessant attraction produced by the ascending current determines a constant afflux of masses of air coming from the north and south, the circulatory system of the winds possesses in general a tolerable regularity. In this part of the terrestrial sphere the aërial masses move uniformly, those of the northern hemisphere in the direction from north-east to south-west, and those of the southern hemisphere in the direction from south-east to north-west. Thus two atmospheric currents do not cease to flow obliquely to meet each other. These are the " trade-winds," which the ancients hardly knew, and of which the complete discovery was reserved for the great Spanish and Portuguese navigators. Among all the marvels that they discovered in the tropical regions, none astonished them more than these breezes, blowing invariably from the same point of the horizon. Accustomed to the changing and irregular winds of the European seas, the sailors were almost terrified at the constancy of these winds, which carried them towards the equator, and never flowed back again in the direction of their country. The companions of Columbus saw in it the effect of the craft of the devil, and asked with terror if all this movement of the aërial waves was not directed towards some gulf, situated at the limits of the world. Nevertheless, navigators were soon familiarised with the tranquil latitudes traversed by the trade-winds. The Spanish sailors formerly called the tropical

part of the Atlantic Ocean *el golfo de las damas* (the ladies' sea), because there one could confide the helm of a ship to a young girl without danger. Indeed, according to Varenius, the sailors setting out from Acapulco could fall asleep without paying attention to the rudder, with the certainty of being conducted by the wind across the calm waters of the Pacific to the shores of the Philippines. Struck with the great advantages which the constancy of the trade-winds present to navigation, the English have given them this name. The old term, *vents alizés,* by which the French sailors designate them, indicates an equal continuous and regular movement.

Still, it must be said, these winds have not such a certain march that we can count on them, as on the return of the heavenly bodies. The alternations of the seasons and the great atmospheric disturbances make them oscillate from right to left, retard or accelerate them, and sometimes even neutralize them for a time. In the neighbourhood of the coast, the extremes of heat and cold which succeed each other on the continents cause the winds to deviate in their course, and consequently it is only in the open sea, at a great distance from the coast, that the sails of ships are swollen by a breeze blowing almost constantly from the same point of the horizon ; but even then the wind is stronger in the morning and evening than during the heat of the day. In the Atlantic, bordered on each side by continents tolerably regular in form, the trade-winds have the most uniform speed. In the Pacific, the multitude of islands scattered over the surface of the waters modify greatly the normal condition of the winds, and over a very great extent of their natural domain the trade-winds are transformed into monsoons. To the north of the equator the north-east winds only blow in a constant manner between the Revillagigedo, and the Marianne Islands. As to the southern trade-winds, they are still more restricted; they commence with the group of the Gallapagos, at 1620 miles from the coast of America, and reach no further west than the Archipelago of Noukahiva and the Low Islands.

In rushing one against the other, the two opposite winds hold each other in check, and consequently their force is neutralized ; it is thus that a circular zone of calms, variable winds, and sudden aërial eddies is formed all round the earth, which, according to the seasons, occupy a breadth of from 155 to 620 miles on the surface of the sea. Nevertheless, we must not suppose that, in this zone of so-called calms, the air is generally tranquil ; but the atmosphere is more often in a state of equilibrium there than in any other part of the surface of the globe. According to the *Pilot Charts* of Maury, the mean duration of the calms of the Atlantic between the 5th and 18th degrees of north latitude is to that of the winds in the proportion of 98 to 802, or of 1 to 8. During the period when the calms are most frequently produced, that is to say, in the month of November, and in the space comprised between the 12th and 13th degrees of north latitude, they prevail on an average half as much as winds coming from any point whatever of the horizon.

We can understand that this zone which separates the two trade-winds of the north and south must necessarily be altered according to the seasons by the position of the sun, since it occupies on the circumference of the globe precisely those latitudes where the atmospheric strata are most strongly heated by the solar rays, and where the vertical movement of the expanded air is produced. When the sun, after the 21st of September, crosses the equatorial line to tend towards the tropic of Cancer, the centre of the trade-winds, and consequently of the band of calms, moves at the same time towards the north ; on the contrary, when the sun

returns to the tropic of Capricorn, the most heated zone of air is gradually brought back to the south with the whole circulatory system of the trade-winds. At the end of March the northern limit of the equatorial calms of the Atlantic is found, on an average, towards the 2nd degree of north latitude, while at the end of September this same limit attains ordinarily the 13th or 14th degree. As to the southern limit, it oscillates in the same ocean from 1 to 4 degrees of north latitude. In the equatorial regions of the Pacific, the zone of calms is similarly displaced from month to month, following the march of the sun, and its breadth varies from 135 miles in the month of February to more than 840 miles in the month of August. In this respect the analogy is almost complete in the two great oceans. In consequence of this annual periodicity, the whole aërial system incessantly oscillates according to the relative position of the sun, and it is for this reason that, in the northern hemisphere, the north winds, being violently attracted towards the south, are much stronger in winter. Besides these, there probably exist monthly and semi-monthly oscillations resulting from the declination of the moon.

The central part of the zone of calms, which may be considered as the meteorological equator of the world, does not correspond with the equator properly so-called. On the earth, as in the higher organisms, the principal seat of life is placed out of the geometrical centre. The complete system of the winds inclines towards the northern hemisphere, and it is to the north of the line that the girdle of the equatorial calms is at all seasons developed. This phenomenon, which might seem at first sight strange, results from the grouping of the greater part of the continental lands in the northern hemisphere, and from the difference of temperature, which must be, at least for one part of the world, the result of this unequal distribution of solid and liquid. It is also in the northern hemisphere that we find the desert of Sahara, the true geographical south of the earth, that immense extent where wooded tracts are relatively few, and where the reflection from the burning sands and rocks vaporizes the clouds which the atmospheric currents bring. The Sahara, and in a less degree all the tropical countries of the northern hemisphere, act as a great centre towards which the aërial masses flow. It results from the tables drawn up by Dove, that the mean temperature of the year is more elevated (92° F.), towards the 10th degree north latitude, than it is at the equator itself (91·5° F.), while the mean balance is stronger towards the 20th degree of latitude (94° F.), than in any other region of the world. The high temperature of the continents thus forces the southern system of winds to encroach upon the northern system.

On the subject of clouds and wind-currents over the Atlantic "doldrums," which extend from about 8 degrees to 13 degrees north latitude, some important observations were made by Mr. Ralph Abercromby on board the steamer *Tongariro* during her voyage from Rio Janeiro to Teneriffe in June and July, 1885.

"Practically clouds in these latitudes may be taken as belonging to three levels: a small cumulus, low down; a middle layer of some stratiform cloud; and a high-level cirrus. Any one of these may appear by itself, or all may be present simultaneously. The depth of the various air-currents which drive these clouds, seems to be of great importance in any general theory of the circulation of the atmosphere in the equatorial regions.

"South of the equator, the low or middle clouds over the south-east trade, which we picked up in 10 degrees south latitude, invariably came from some point to the right of the surface-wind, when you stood with your back to it; *i.e.* if the surface-wind

was south-east the clouds would drive from about east-south-east. This is the usual rotation of upper currents in the southern hemisphere.

"But, north of the line, when for reasons which cannot be discussed here, the south-east trade did not turn to south-west, as might have been expected, the upper currents continued to follow the rotation of the southern, and not that of the northern hemisphere; that is to say, the upper currents over the south-east surface-wind continued to come from some more easterly point. In the "doldrums" also, the same rule obtained, and the middle cloud-layer over some "cat's-paws" of south-east wind drove from the east.

"A second series of observations was taken in December last on board the s.s. *Drummond Castle*, during part of her voyage between Lisbon and Cape Town, with much better appliances for observing clouds than on the former voyage.

"In the north-east trade, from 30 degrees north latitude down to the doldrums in 5 degrees north, the upper layers of cloud invariably came from some point to the left of the surface-wind. When you stood with your back to it—*i.e.* if the surface-wind was from north-east, the higher clouds would come from the east, or south-east, or even south by west. This is the usual rotation of upper wind-currents in the northern hemisphere. As far north as 20 degrees north the middle clouds came from south by west, and in 10 degrees north this current had descended to the level of the low cumulus, and the middle clouds drove from west.

"But when the doldrums were entered in 5 degrees north, a totally different wind-system became apparent. Over the oily calm of that district was just detected through the universal haze and gloom, a middle current from the east; and when, in a few hours, the vessel picked up the south-west monsoon of the Gulf of Guinea, here coming from south by west, the low clouds drove from south-east. This continued till the line was reached, and the single observation obtained of high cirrus in 1 degree north latitude showed an easterly current at that level. Thus, for 8 degrees north of the equator the rotation of the upper winds was that proper to the southern hemisphere, for south-east and east were over a south-west surface-wind instead of west or north-west, as might have been expected. This is the more curious because the surface-wind has the south-west set proper to the northern hemisphere.

"But the greatest interest of this last observation is to be found in the extraordinary analogy which the wind-system over the Gulf of Guinea presents to the wind-system over the north-west monsoon in the Indian Ocean. In that region, as the north-east monsoon crosses the line and turns to the north-west, the upper currents are those proper to the northern hemisphere; that is to say, the low and high layers of cloud come from north and east respectively. Now we see that both in the Gulf of Guinea and mid-Atlantic, as the south-east trade crosses the line, it carries the rotation of the higher currents proper to itself up to the doldrums.

"After crossing the equator in the *Drummond Castle*, the wind turned to south by east or south-south-east, and as far as 18 degrees south, beyond which we need not follow them, the upper currents were either identical in direction with the surface-wind, or else a very little more easterly; that is, they followed the normal rotation of their hemisphere.

"Another very important result of these observations, as far as they have gone, is that the highest current between the equator and the doldrums is always from some point near the east, whatever the westerly set of the surface-wind may be. The velocity of this current does not appear to be very great; though, of course, the height is considerable.

CHAPTER XXX.

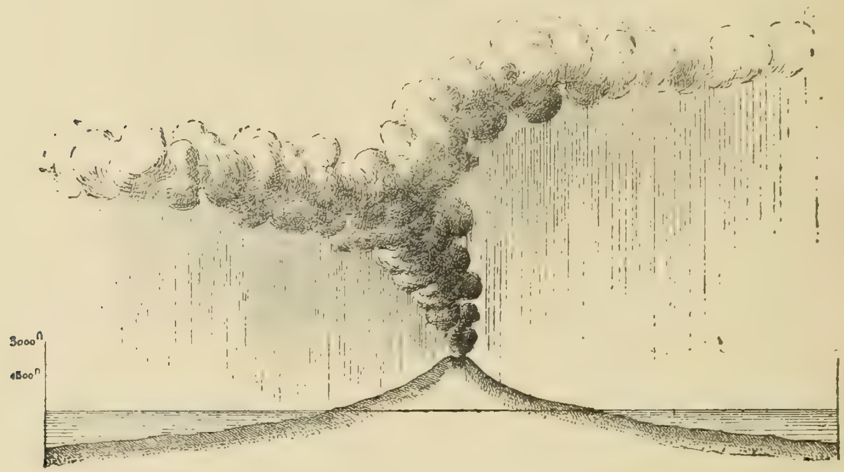
COUNTER TRADE-WINDS, OR RETURNING WINDS.

THE aërial masses brought by the two trade-winds cannot be incessantly accumulated in the region of equatorial calms; they expand, rise to several miles of height, then, after having been mixed, and even partially crossed, they divide anew into two great returning currents which flow in an opposite direction in the upper regions of the atmosphere. Thus, as the natural philosopher Halley, who was the first to give a theory of the trade-winds, affirmed nearly two centuries ago, it would be absolutely impossible, if these two atmospheric counter-currents did not exist, that the equilibrium of the air could be established on the surface of the globe; that which the breath of the trade-winds brings to the equator must necessarily be carried back by other winds towards the poles. The movement of the graceful clouds, so light that we see them from below floating in the heights of the air in the opposite direction to the trade-winds, is an incontestable proof of the existence of these higher returning currents. Besides, two great volcanic explosions, often mentioned by savants, have also furnished striking testimony which confirms Halley's theory in an indubitable manner. On the 1st of May, 1812, when the north-east trade-wind was in all its force, enormous quantities of ashes obscured the atmosphere above the island of Barbadoes, and covered the ground with a thick layer. From whence came these clouds of dust? One would have supposed that they came from the volcanoes of the Azores, which were to the north-east; nevertheless, they were cast up by the crater of Morne Garou, situated in the island of St. Vincent, at 125 miles to the west. It is therefore certain that the débris had been hurled by the force of the eruption above the moving sheet of the trade-winds, into an aërial river proceeding in the contrary direction. In the same way, at the time of the terrible eruption of the volcano of Coseguina, in Central America, ashes were carried by the returning trade-winds to the shores of Jamaica, which is no less than 800 miles to the north-east of the crater whence they were thrown.

On the coasts of Africa, and along the Mediterranean, grains of dust, almost imperceptible singly, give another very remarkable proof of the existence of a great returning current in the high regions of the atmosphere. Sometimes a shower of yellow or red dust, resembling powdered brick, falls from the sky. Ships which were in the neighbourhood of Cape Verde, on the coasts of Morocco, or in the waters of the Mediterranean, have had their decks and sails completely sprinkled with these fine particles. Humboldt, who had the opportunity to observe this rain, believed that it was composed of silicious dust raised by eddies of wind on the coasts of the Sahara, while the sailors who witnessed this phenomenon saw in it

only a shower of sulphur. But Ehrenberg, with the aid of his microscope revealed the nature of this dust, which is nothing else, at least in the Atlantic and the Mediterranean, than the silicious skeletons of animalculæ coming from the llanos of South America. It is thus certain that these myriads of organisms, raised to a height in the air by the ascending current of the equator, have met above the trade-winds with a returning current, which has caused them to cross, the immense basin of the Atlantic, and to reach the coasts of Africa, or even of Europe, as far as the basin of the Rhone. The aërial currents have thus become visible, by means of these clouds of infusoria. In 1869 a quantity of red dust fell in Switzerland, the collective weight of which was estimated at 1500 tons. According to Gaston Tissandier, a volume of air 16 cubic feet thick taken from any part of Paris will weigh about 3350 lbs., and will contain small particles of magnetic iron, evidently of cosmic origin. Nordenskjöld also found iron, nickel, and cobalt in the dust collected by him amid the snows of Spitzbergen and Greenland. These

Fig. 102.—Cloud of Cinders from Morne Garou.



he regards as likewise the remains of matter attracted to the earth from the interplanetary spaces.

In the equatorial zone the counter-current of the trade-winds can only commence at a height of from four to five miles above the level of the sea, for the highest summits of the Cordilleras remain entirely bathed in the lower current. The most southern mountain of the Atlantic basin, whence the returning wind has been observed, is the peak of Teyde, in the island of Teneriffe. There the masses of air flowing back from the equatorial zone are already sufficiently low to surround the terminal point of the volcano (only 12,060 feet high) at all seasons. In winter, when the whole circulatory system of the atmosphere has descended towards the south, following the course of the sun, the returning current descends from the higher strata of the air, and strikes the surface of the water near the coasts of Portugal, then turns back again, and makes itself successively felt at Madeira, and on the middle and lower slopes of the peak of Teneriffe. According to the astronomer Piazzi Smyth, it is at an average of 9000 feet of vertical height that the plane of separation between the two aërial rivers flowing in opposite directions is found. At the summit of the mountain the air is carried rapidly from south-

Ocean.

SHOWERS O


ENGLAND
Ireland
FRANCE
SPAIN
GERMANY
SWEDEN
RUSSIA
EUROPE
ITALY
TURKEY
Black Sea
Constantinople
MÉDITERRANEAN
AFRICA
Berlin
Vienne
Lyons
Fernando Po
St. Thomas
Red Hail
Showers of "Blood"
Frequent "

west to north-east, while on the low parts of the island the trade-wind always blows with its habitual regularity. The zone of clouds that it unrolls in an immense veil above the sea and the shores does not extend into that part of the heavens comprised between the two winds blowing different ways, but, on the contrary, it is found at a tolerable depth in the trade-winds. Between the upper and lower currents the air is calm and free from clouds. During the summer season, travellers who climb the sides of the peak of Teneriffe may confidently expect to find an unchanging sky directly after having passed the zone of clouds, from 900 to 1200 feet in thickness, which is spread like a second sea above the ocean. At the change of the seasons, when the two opposing winds strive for victory on the slopes of the mountain, a few days are sometimes sufficient to bring

Fig. 103.—Island of Teneriffe.

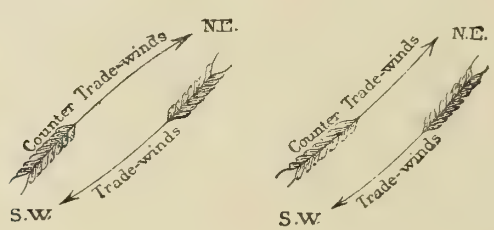
about a change of 3000 feet in the height of the intermediary zone. A battle between the two currents takes place in the sky; soon the trade-wind mounts to the upper slopes of the peak; now it is vanquished, chased from the heights of the atmosphere, and driven with all its system of clouds towards the lower regions. It is principally above the pass of Laguna, between Santa-Cruz and Orotava, that the combat takes place, and in consequence this district of the island is frequently inundated with rains. Piazzi Smyth has described these grand aërial contests at great length in his work on Teneriffe.

In the Pacific Ocean, analogous phenomena to those which occur in the Atlantic have been observed. Goodrich has ascertained that the normal currents of the trade and returning winds make themselves felt at the same time, the one on the

shores of the Sandwich Islands and the lower slopes of all the mountains of the Archipelago, the other on the summit of the volcano of Mauna-Loa.

The direction of the upper counter-current is, like that of the trade-winds, determined by the rotatory movement of the earth. At its return from the equator each particle of air in movement turns towards the east instead of deviating to the west, as in its voyage from the polar to the torrid zone. After having sojourned in the equatorial regions it traverses successively countries whose speed around the axis of the earth is less than its own. In proportion as it retreats from the zone of calms, it thus finds itself in advance of all the subjacent points of the planet, and changes into a wind from the south-west. Below it glides the north-east trade-wind, generally in an opposite direction; but in consequence of the friction of the aërial particles, a stratum of calm air is formed between the two atmospheric currents, where are manifested all the meteoric phenomena due to the contact of the two masses, unlike in heat, moisture, and electric tension. According to Dove, the counter trade-wind would bend more and more to the east, because of the increasing curve of the earth in the direction of the pole. According to Mühry, on the contrary, the direction of this wind would be exactly parallel to that of the lower current, and would curve gradually towards the north, in consequence of the attraction exercised in the polar regions by the

Fig. 104.—Theory of Dove. Theory of Muhry.



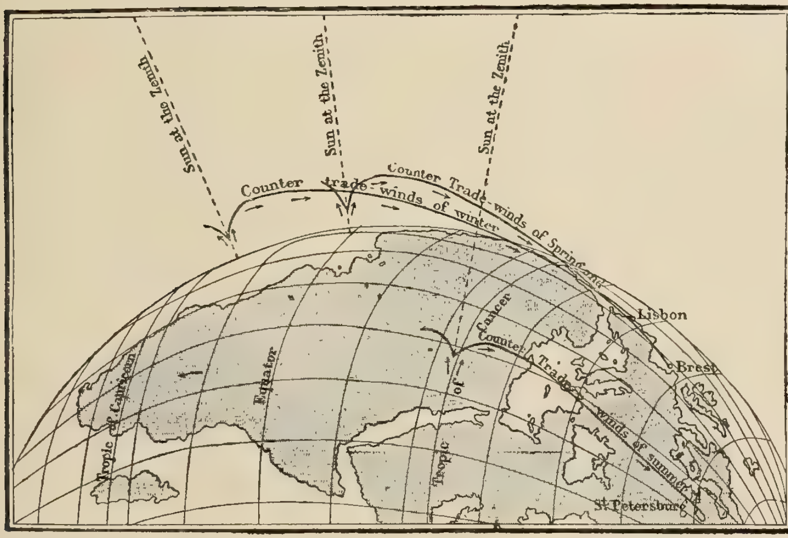
wind which descends towards the equator. This last theory appears the most probable; but it is for direct observation to decide in a definite manner.

One might believe at first that the upper counter-current flows towards the pole, maintaining itself in the high regions of the atmosphere, and that the polar wind, on its side, more compact in its particles, because of the cold, always glides over the surface of the globe. It is only rarely that it is so. In a somewhat undecided region which, for the North Atlantic, oscillates alternately, according to the seasons, from the 21st to the 25th degree of latitude, the returning wind commences to descend from the heights of the sky to the surface of the sea, and strikes against the aërial masses which flow from the poles towards the burning latitudes of the equator. The zone where this shock of the winds occurs is considered as the outer limit of the trade-winds; but it is incorrect to give it the name of the zone of tropical calms, for if the complete equilibrium of the atmosphere is more frequent there than in the regions bordering on the north and south, yet, nevertheless, the calms hardly last more than a day in the space of two or three weeks. During the summer of the northern hemisphere, when the sun is at the zenith of the tropic of Cancer, the counter trade-winds may make themselves felt with tolerable regularity as far as the latitude of the north of Germany, or of St. Petersburg. In autumn and in winter the domain of these returning currents is unceasingly restricted towards the north, and increases to the south. Brest and

then Lisbon are its extreme limits in the northern hemisphere, till the sun resumes its march to the north.

Why does the upper current thus descend from the heights of the atmosphere during the greater part of the year? Doubtless because it carries with it enormous quantities of watery vapour, which renders it heavier than the cold dry air from the poles. Owing to its temperature, it first rises higher than the Cordilleras, then, being gradually cooled, it sinks under the weight of moisture that saturates it, and when it finally enters the temperate zone, it falls to the surface of the earth with clouds and rains, and strives for supremacy with the polar current. The difference of specific cold between the opposed masses of air must be very small, since by turns each gains the advantage. Often the current coming from the torrid zone, recognisable from below by its trains of *cirri*,

Fig. 105.—Variations in the Trade-Winds.



cannot reach the surface of the ground, and maintains itself as far as the pole in the upper strata of the atmosphere, whilst the wind that blows from the frigid zone forms a continuous current over the earth, from the pole to the equator. Still, we must consider the south-west wind as the prevailing wind of the northern temperate zone, for it makes itself felt there much more frequently than the contrary current, the proportion of the former being nearly double between the 50th and 55th degree of latitude. We know that sailing vessels formerly required 46 days on an average for the voyage from Europe to the United States, whilst the return, facilitated likewise by the Gulf-stream, was accomplished in 23 days. The winds from the south-west and west, which are nothing else than the counter-current of the trade-winds, blow with such regularity in these parts, that one might give the names of "ascending voyages" to the passages from Europe to America, and "descending voyages" to those in the opposite direction. Corresponding phenomena occur in the southern hemisphere; there it is the north-west winds which blow most frequently beyond the southern limits of the trade-winds.

Thus the two permanent winds which are drawn towards the equator by the

expansion of the warm air have each their proper domain, limited in one direction by the calms of the equinoctial line, in the other by the irregular winds of the temperate zone. Still these limits oscillate incessantly from month to month and from season to season, and one cannot indicate them in a precise manner. On a general map of the trade-winds, it is sufficient therefore to trace the extreme frontiers of these currents for winter and summer. On an average, the space in the Atlantic over which the north-east wind blows, embraces from 18 to 20 degrees of latitude, or from 1245 to 1275 miles; in the South Pacific the domain of the south-east trade-wind would not be less than 30 degrees, or 2045 miles.

Between the atmospheric and oceanic currents the analogy is evident. The maritime river which is founded at the junction of masses of water coming from the two polar seas, corresponds to the equinoctial zone, where the trade-winds of the north-east and south-east meet. Obliged to extend laterally while maintaining themselves under the common level of the maritime reservoir which contains them, the tepid waters of the equatorial current flow afterwards towards the north-east parallel to the counter-current of the trade-winds, which has risen into the heights of the atmosphere. Under the influence of the same causes, the two oceans of air and water move in the same direction, and their movements are subject to the same oscillations to the north or south during each alternating period of the seasons. In summer, when the Gulf-stream is prolonged far into the northern sea, the double system of the north trade-winds and counter-winds advance several degrees into the temperate zone, while during the winter it flows back again towards the tropic of Cancer, followed by the Gulf-stream, which bends gradually towards the south. The resemblance would be complete if the water were an elastic and compressible fluid like air, and were not enclosed in a basin whose borders it could not pass. The difference of the means explains the difference of the currents which the heat of the sun and the terrestrial rotation produce in the ocean and in the atmosphere.

CHAPTER XXXI.

THE TRADE-WINDS OF THE CONTINENTS.—THE MONSOONS.—ETESIAN WINDS.

THE trade-winds, as we said, have not the same regularity on the continents as over the seas. On the surface of the ocean the masses of moving air are not arrested by any obstacle; they are propagated freely towards the equatorial zone, and can scarcely be turned from their route by the attraction of any marine centre of heat, as the temperature of the water only increases or diminishes very slowly, and the oscillations of the thermometer from day to night do not attain 36° F. In the midst of the large islands and the continents it is no longer so. Their mountain-chains oppose the course of the winds, and cause them to change their direction; forests, prairies, sheets of inland waters, plateaux with long slopes, hilly countries, large plains, and the innumerable variations of topographical relief, are variously heated by the sun, and by this very circumstance turn aside or repel the wind which blows from the neighbouring seas. In the higher regions the current can, it is true, continue its normal movement above the plateaux and the mountains; but below the uneven surface of the country is traversed by irregular winds. Here the band of equatorial calms is completely obliterated, there it is enlarged in an abnormal manner; the winds are deflected variously on one side or the other, and are directed towards that country whose air is most expanded by the rays of the sun. Nevertheless, it must be said that only a very insufficient number of meteorological observations have as yet been made in the greater part of tropical countries.

Still, we cannot doubt but that the trade-winds blow over vast continental tracts, as well as over the surface of the seas. In fact, the want of rain and the almost complete absence of vegetation in all that part of Africa known by the name of the desert of Sahara, prove in an indubitable manner the existence of a regular wind from the north-east. After having passed the high plateau of Asia, and having discharged itself of the greater part of its watery vapour, this atmospheric current traverses obliquely the whole of Africa from the banks of the Nile to those of the Niger. On this enormous track of nearly 3000 miles it only lets rain fall on some mountain-summits, such as the Jebel-Hoggar, and scarcely casts a single cloud on the unchanging azure of the sky. On the western coast of the Sahara, the burning wind called the *Harmattan* is nothing else than the north-east trade-wind more or less turned from its course because of the neighbourhood of the sea. Towards the 17th degree of north latitude, on the southern frontiers of Sudan, clouds are at last formed in space, abundant rains penetrate the soil, and the aridity of the desert gives place to a fine vegetation; this is, because the

domain of the permanent winds terminates there, to be replaced by the zone of equatorial calms with an ascending current loaded with aqueous vapours. In the southern part of Africa, the trade-winds of the south-east make themselves regularly felt, and according to the testimony of Livingstone, traverse the entire continent from the mouths of the Zambesi to the coast of Angola. On the other side of the great strait of the Atlantic, the tropical regions of South America are likewise refreshed by the constant breath of moist winds from the south-east. Brazil, Paraguay, a great part of the Argentine Republic, Bolivia, Peru, Guiana, and Columbia, are comprised in this great meteorological region. The trade-wind, turned back under the equator in an easterly and westerly direction, ascends with a uniform force the valley of the Amazons, penetrates into the gorges of the Andes, and even crosses by all the defiles the high barrier of mountains ; but sheltered by this enormous rampart the shores of the Pacific are not subjected to the influence of the east wind. The vessels which sail in the open sea have to traverse from 125 to 625 miles, according to the latitudes, before a gust of the trade-wind, descending from the summit of the Andes, comes to swell their sails and drive them to the coast of Australia.

Even in those parts of the world where the tropical winds cease to be permanent, the oscillations and deflections of the atmospheric current present in general a periodical character and occur regularly, according to the course of the seasons. Among the regular return winds we may cite principally the "monsoons" of India and Arabia. The Arabic term for these meteoric phenomena, *mausim*, signifies change, season ; and they are so named because they divide the year in the most exact manner into two totally distinct periods. During the great heats of summer, the arid plateaux of Central Asia, and even the plains of Hindostan, much more heated than the sea, act like a great respiring pump ; the air which rests above this part of the Asiatic continent expands, and in consequence new aërial masses flow without cessation from the Indian Ocean to the countries on the north. According to Dove, the trade-wind of the south-east, carried away by this general displacement of the air, would itself cross the equator, enter into the northern hemisphere, and transform itself gradually into a monsoon from the south-west, because of the great speed it acquires at the equator. Still it is not probable that it is so, for the monsoon has not the same vertical height as the trade-winds, and its direction is not uniformly from south-west to north-east, as on the coasts of Malabar; in the valley of Scinde and in that of the Irawaddy it is directly south ; at the extremity of the Gulf of Bengal, in Siam, at the eastern angle of the Asiatic continent, its direction is from south-east to north-west, perpendicular to the coasts which attract the wind.

Saturated with the moisture which has evaporated from the great cauldron of the Indian Ocean, the monsoon inundates the coasts of Malabar with torrents of rain, deluges the shores of the transgangetic peninsula, and then strikes against the high mountains of the Himalaya, and other chains, which border the plateaux of Central Asia on the south ; but it does not cross this barrier. By its clouds charged with rain, which are rent by the escarpments of the inferior peaks, we see clearly that the sea wind does not pass the altitude of 4950 to 8250 feet, and that above it another aërial stratum is moving in the heights. The movement which carries along this elevated stratum is the same as that of the monsoon from the south-west; but we recognize by its long trains of *cirri*, from 16,500 to 25,500 feet high, that great returning current, or counter trade-wind, that blows at the same elevation above the Atlantic in the neighbourhood of the Canaries.

When the sun, in its course over the ecliptic, returns towards the tropic of Capricorn, the centre of attraction is at the same time displaced in a southerly direction. The monsoon of the south-west ceases to tend towards the great peninsulas of Asia, the regular wind from the north-east recommences to blow, and the currents of attraction in the southern hemisphere turn back towards the islands of Sunda and Australia. Owing to this regular alternation, which was a surprise to the ancient Greek navigator Hippalos, the mariners of the Indian Ocean may count beforehand on a favourable wind which by turns will drive their ship before it for the two passages, going and returning; and they have not to dread those prolonged calms which are the bane of sailing vessels in the equatorial zone of the Atlantic and the South Sea. The circulatory system does not in any place pass beyond the lower strata of the aërial ocean, and we may easily perceive above the islands of Sunda and Australia, as well as over the sides of the Himalayas, the constant progress of the clouds which are brought by the regular trade-winds. A volcano of Java, observed by Junghuhn, affords a remarkable example of this. From its summit, about 9900 feet high, a column of vapour escapes all the year round which bends gracefully in space, and directs itself towards the west, or north-west in a long whitish cloud, and it is in precisely the opposite direction that the monsoon blows during six months of the year, on the slopes as well as at the foot of the mountains.

The monsoons of the East Indies are not the only winds which break the uniformity of the trade-winds. In all those parts of the tropical zone where the shores of the continents are disposed parallel to the equator, the winds alternate regularly, in consequence of the greater rarefaction of the air which occurs now on the earth, now on the sea, according to the position of the sun. Thus, during the greater part of the year, the African coasts, which stretch from the Bight of Benin to Cape Palmas, attract the monsoons of the Gulf of Guinea. These masses of air, changing their direction, turn back to blow in a north-easterly direction and rush rapidly towards the great furnace of the Sahara, where the overheated atmosphere is usually more expanded than in any other country of the world. Towards the month of January, when the Sahara itself has become colder than the equatorial seas and the banks of the Congo, the trade-wind of the north-east re-assumes the supremacy, and traverses the whole of Northern Africa obliquely to the south, towards the coasts of Southern Guinea. Very violent at first, it soon becomes weaker, and hardly lasts but two or three weeks, when it again gives place to the marine monsoon. During its short prevalence the current coming from the desert does not cease to bring with it a white dust having the appearance of a thick fog. It is the sand of the Sahara, which in the regions situated immediately to the north of Guinea is almost white, while further the dust raised from the ground by the *Harmattan* is nearly red.

On the coasts of Chili, on those of California, in the islands of the Pacific, around the Gulf of Mexico and the sea of the Antilles, analogous phenomena occur. In summer the valley of the Mississippi and the plateaux of Texas are traversed by real monsoons, which distribute the rain over that part of the continent, and then are in turn replaced by those dangerous winds from the north or north-east (*nortes*), which are themselves trade-winds, more or less turned aside from their route. On their side, the western shores of Mexico present a similar alternation of winds, those from the south-west coming in summer, and those from the north-east in winter. On coasts parallel or merely oblique to the path of the trade-winds, a part of these winds is not brought back, as in the West Indies or at Guinea, but it is more or

less attracted by the centre of heat, which lies out of its regular course. It is thus that on the coast of Morocco, and near the archipelago of the Canary Islands, the wind from the north-east is subject to a considerable deviation towards the African continent, and is sometimes transformed into a wind from the north. In the same way the plateaux of New Granada and the *llanos* of Venezuela turn aside the normal current which penetrates into the sea of the Antilles, and oblige it to blow perpendicularly to the coast. Thus a periodical breeze (*los brisotes*) is produced, which may be considered as an intermediate wind between the monsoons and the trade-wind properly so-called.

The winds of the Eastern Mediterranean, to which the ancients gave the name *Etesian* winds (from *étos*, year), are also nothing else than monsoons. These are

Fig. 106.—Trade-Winds and Monsoons of the Atlantic.

atmospheric currents drawn from the north towards the continent of Africa, by the powerful centres of attraction formed by the sands of Egypt and the Sahara. During nearly the whole summer the aërial masses which repose above Southern Europe are thus carried away to the coasts of Africa, and even in temperate countries with variable winds, like Italy, Provence, and Spain, it is affirmed that the predominating currents are those from the north. Owing to this general movement of the air, the passage from Europe to Africa is accomplished on an average more rapidly than the returning voyage; for the sailing vessels, which traverse the Mediterranean between France and Algiers, the passage from the north to the south is about a quarter less than the route in the opposite direction. All the northern part of the Balearic Islands, and especially of Minorca, is laid waste by a wind from the north, which stunts vegetation, and causes all the trees to lean in a southerly direction.

CHAPTER XXXII.

LAND AND SEA BREEZES.—WINDS FROM THE MOUNTAINS.—SOLAR BREEZES.—LOCAL WINDS.—THE SIMOON, SCIROCCO, FŒHN, TEMPESTS, AND MISTRAL.

BESIDE the lateral deviations which occur twice in the year, the trade-winds are subject along the coasts to rapid daily deviations. The whole outline of the continents is bordered, so to speak, with a fringe of breezes produced by the difference of temperature between the land and the water. During the day the countries of the coast-line are heated much more rapidly than the surface of the ocean. Towards ten o'clock in the morning, after a shorter or longer period of calm, a rupture of equilibrium occurs between the aërial masses, and the fresher atmosphere reposing above the waters tends towards the land, there to replace the expanded air which rises into the higher regions. Little by little this movement of translation, which at first only made itself felt in the neighbourhood of the coast, communicates itself to all the surrounding atmospheric strata, and soon the breeze moving nearer and nearer through the ocean of air, occupies a tolerably large space above the sea and the continent, which it unites as an iron plate unites the two branches of a magnet. During the night the ground loses by radiation a great part of the heat that it had received, while the sea preserves pretty nearly the temperature of the day. The equilibrium is again disturbed, but it is now in the direction of the sea; the breeze is brought back, and blows in the opposite way. It is thus that in the space of 24 hours the breeze oscillates from land to sea, and from sea to land, by a motion of ebb and flow, analogous to that of the tides. In the countries of La Plata these alternate breezes from land and sea present such a regularity that they have received the name of *virazones* (gyrations). Around Tahiti they also succeed each other with such punctuality that a vessel could for several consecutive nights make the tour of the island, and always with the wind behind it.

These breezes, which one might also call daily monsoons, co-exist with the movement of the trade-winds, and are in consequence carried along in the general circuit. Instead of being at right angles to the coast, they more often form with it an acute angle; they blow cross-ways, as Captain Dampier said. Nevertheless, it is not only in the domain of the trade-winds or along the borders of the ocean that the littoral breezes occur; they blow everywhere where a considerable difference of temperature exists between the land and the water, wherever the fresh air of the sea or of a lake goes to fill the vacuum left on the coast-line by an ascending current of warm air. A remarkable example of it is seen in the narrow Adriatic Sea. There, during each fine day, the breeze rises in the centre of the gulf, and takes its direction at the same time in two contrary ways—on one side towards the

shores of Italy, on the other towards the islands and mountains of Istria and Dalmatia. During the night the coasts that surround the waters of the Adriatic send back to the sea, as to a common centre, the fresh air which they have received; to divergent currents of the day succeeds a wave of convergent breezes.

In the same way the mountains have their own system of breezes alternating with a regularity similar to that of the land and sea breeze on the coasts of the ocean. In the day, especially in summer, when the summits of the mountains are exposed to all the intensity of the solar rays, and receive a considerable quantity of heat, which causes their temperature to approach that of the valleys, the air reposing on the summits expands and rises. At the same time the air of the plains which lie at the foot of the mountains is itself expanded in greater proportions, so that an ascending current is produced from the base to the summit of the peaks, in all the valleys, and over all the escarpments. The atmospheric strata of the plain move in the direction of the heights with all the more impetuosity the more strongly heated the summits have been by the sun. In certain valleys, especially those of the Stura, and other Alpine rivers which water the plains of Piedmont, the ascending wind has such force that the greater part of the trees are uniformly inclined towards the mountains. Pollen, remains of plants, insects, and butterflies, are carried away by the current of air, and by their débris soil the whiteness of the snow. In the night, phenomena of an opposite kind are produced, but with less intensity; the high mountains whose summits rise far into the sky, lose their heat by nocturnal radiation more rapidly than the valleys, the sheets of air which surround them are chilled and descend again, in part, towards the plains from which they had ascended a few hours before. Thus an exchange between the two zones is established, an ebb and flow, a rising and falling atmospheric tide, regulated in its intensity by the variations of the temperature; and here we see again, as in the coast breezes, the rotary movement pointed out by Dove.

As an example of these breezes, called in the French Alps *pontias*, *rebats*, *aloups du vent*, we may cite the three aërial currents which flow incessantly in the valleys of Savoy, unless the local system of atmospheric currents be modified by tempests. These three streams of air are those of Faucigny, Tarentaise, and Maurienne. The first traverses the valley of the Arve from Geneva to Mont Blanc; the second moves in the valleys of the Isère, and its tributary, the Doron; the third alternately ascends and descends the valley of the Arc towards Mont Cenis and the pass of Iseran. Ordinarily, the ascending wind commences towards ten o'clock in the morning in the valleys of Savoy, and the descending current flows back again towards the plains at nine o'clock in the evening. In certain places, it is called *matinière*, because it makes itself felt, most of all, before the rising of the sun. M. Fournet, who has for a long time studied these phenomena of atmospheric tides, has ascertained that the passage, from the ebb to the flow, is especially rapid in the narrow defiles, while in the large basins the alternation is produced after a series of aërial oscillations and gusts of wind in the opposite direction. Each valley owes a special atmospheric condition to its particular form; in one, the successive breezes are slow and undecided in their pace; in another, they alternate abruptly, and with violence, producing in the space of a few hours variations of temperature of 35, 45, and even 55 degrees. In general, the breezes are regular in the regular valleys, and only present remarkable peculiarities at their issuing into the plain, or else at the confluence of two gorges. Among these winds with peculiar motions, a breeze of the Rhenish basin may be mentioned known under the name of the *Wisper-wind*. Emerging above Lorch,

from the narrow valley of the Wisper, which is filled with woods, and so situated as to be subject in its different parts to all the extremes of temperature, this breeze generally blows till eight, nine, or ten o'clock in the morning, then crosses the Rhine, strikes against the rocks of the left bank, and divides into two currents, one of which re-ascends to the south towards Bingen, increasing itself on the way by several small tributary winds; while the other, which is weaker, descends to the north towards Bacharach.

Even in the plains and countries but slightly varied in surface, daily breezes may succeed each other regularly, because of the local differences of temperature produced by the progress of the sun. In the morning, as soon as the sun rises, the temperature, which had fallen to its lowest because of the nocturnal evaporation, increases rapidly, the air expands and spreads towards the colder spaces which extend on the side of the west; a little wind from the east results from this, which becomes gradually a wind from the south-east, in proportion as the sun mounts above the horizon. At noon the expanded air spreads in the direction of the north; and finally, towards the evening, it is on the eastern side, where the aërial strata are chilled, that the surplus air, still heated by the solar rays, directs itself. Thus, when the atmosphere is not agitated by a general wind, a breeze turning regularly round the horizon in the same direction as the sun must be produced. In the northern hemisphere this movement of gyration is accomplished from east to west by the south; in the opposite hemisphere it is by the north that this diurnal breeze effects its gradual revolution from east to west. In mountains the phenomenon is more complex, on account of the ascending and descending breezes, which are intermixed with the gyrating ones. It is remarked, however, that the greater part of the local winds, determined by the difference of temperature, tend towards the west in the morning, then turn gradually in an opposite direction, and blow towards the east when the sun is sinking. These are the *solaures* (*solis aura*) or solar winds of the Department of the Drôme.

As to the local winds which characterise certain regions, they originate in the unequal distribution of heat. Such are the *khamsin* of Egypt, the *pampero* of the Argentine Republic; such, above all, is that aërial current to which the name of Simoon, or "poisonous," is given in the Sahara. As soon as this wind commences to blow, the panting traveller can scarcely breathe; the air is burning and dried up, as if emerging from the mouth of an oven; the heat, increased by the radiation of innumerable grains of sand which float in the atmosphere, rises rapidly to 113, 122, and even 133° F.; the sun is veiled, and every object assumes a violet or dark-red hue, while space is filled with dust. In order not to be smothered by this suffocating air, travellers must envelop their faces in their garment, and the camels bury their necks in the sand. But the simoon is not always accompanied by clouds of dust. Palgrave, who endured a violent simoon in the desert of Arabia, saw not a single cloud of sand or vapour in the sky, and could not explain the sudden gloom which had invaded the atmosphere.

In Sicily and in the south of Italy, a warm wind occasionally blows from the south, which is considered as a sort of simoon, and is saturated with moisture in passing over the Mediterranean; this is the scirocco. Usually it is not very rapid, and its gusts are interrupted by stifling calms; the surface of the water is hardly agitated, a mist of vapours broods on the horizon, and the sun hides itself behind a veil of whitish clouds. Under the enervating influence of this wind from the south, all exertion becomes painful; but still the terrible phenomena, which occur during the simoon, have never to be dreaded.

In the Alps of Switzerland the south wind is known under the name of *fœhn*, a word derived from *favonius*, the southern wind of the Romans. What is, then, the origin of this current? Has it originated in the Sahara, as Messrs. Desor, Martins, and Escher von der Linth believe, and has its burning breath first served to melt the ancient glaciers of the Alps? Or is it simply a counter trade-wind descended from the heights of the atmosphere, and does it come from the Atlantic and the Carribean Sea, as Dove asserts? Would not the moisture which it brings tend to enlarge the vast rivers of ice? The latter seems probable; but however it may be, the fœhn frequently changes its course, and whether or not it is a continuation of the Mediterranean scirocco, the inequalities in the relief of the mountains modify its character singularly. In rising over the slopes, the air expands more and more in consequence of the lesser atmospheric pressure, and it loses a great quantity of heat; from the warm wind, which it was at the foot of the mountain, the fœhn becomes a cold current. The ridge once crossed, the aërial mass, which descends again towards the plains, is gradually compressed by the upper strata, and the quantity of caloric, which had disappeared because of the expansion, is reproduced; the cold wind of the summer is heated again to blow in the valleys. This is a remarkable phenomenon in the mountains which separate Valais from Piedmont and Lombardy. From being very warm at the entrance to the Italian gorges of the Alps, the atmospheric current from the south is cooled by from 35 to 55 degrees in passing over Mont Rosa; it lets fall rain and snow in abundance; then, after having descended again on the opposite slopes, it brings to the peasants of Switzerland something of the burning climate of the tropics.

As to the fearful tempests or *tourmentes* which occasionally surprise the traveller on high mountains or in the snowy plains, they may result from winds blowing from almost any point of the horizon. It is a terrible thing to be assailed by one of these phenomena. The white masses carried by the gusts of wind hide all surrounding objects. The unhappy people lost in this storm see neither the neighbouring slopes nor the sky above their heads, nor even the path beneath their feet. Deafened by the noise of the tempest, blinded by the powdery clouds which lash their faces, frozen by the snow which hangs in stalactites to their hair and changes their clothes into stiff and heavy masses, the travellers soon lose their way, and sink stupefied by the cold. Hundreds of corpses of men and horses, which have fallen here and there in certain passes of the Karakorum and the Himalayas, recall these terrible snow-storms, which have prevailed over these mountains. Accidents of the same kind are very numerous also on the *paramos* of India, Chili, Bolivia, and Peru. Even in the Pyrenees and the Alps, where the most frequented passes are provided with hospices, where travellers surprised by the whirlwind of snows may take refuge, many unfortunate persons perish every year in these *tourmentes*.

The countries to the south of France have also to submit to the effects of a wind which is a real scourge; it is the wind from the north-west, to which popular imagination has given the name of "master" (*mistral, magistraou, maestrale*). It is caused, like the alternate winds from the mountains, by the juxtaposition of two surfaces unequally heated. This aërial current is unhappily well-named, for its speed, comparable sometimes to that of the hurricane, suffices to uproot trees and throw down walls. "The *melamboreas*," says Strabo, "is an impetuous and terrible wind, which displaces rocks, precipitates men from their chariots, and strips them of their vestments and arms." The Gauls of the valley of the Rhone saw in it their most dreaded god; they raised altars and offered sacrifices to it;

the Provençals considered it with "Durance" and the "Parliament" as one of their three great calamities. This wind makes itself especially felt in winter and spring, when the Cevennes, covered with snow, have become relatively very cold, and the sea-shores continue to be heated daily by the rays of the sun; then the masses of air roll in volumes from the summit of the mountains, to replace the ascending current of the expanded atmosphere, which is formed above the region of the coast-line. During the night, however, the low lands situated at the base of the mountains lose their heat by radiation, and the afflux of cold air diminishes, to recommence on the morrow, when the sun warms the atmosphere of the plains anew. In summer, the difference of temperature is less between the shores and the desert escarpments of the Cevennes. The mistral is very feeble during this season, or it even entirely ceases.

In the middle of the Central Mediterranean the mistral is still so strong that the fogs raised by it on the north coast of Minorca are occasionally transported to the south coast. Here this wind, which prevails for two-thirds of the year, is still dry, as on the French seaboard. But on reaching the shores of Africa the "black bise," as it is called, is already charged with vapours, bursting in violent storms against the steep Algerian coast ranges. It is the same wind to which has been given the ominous name of the "Majorcan carpenter," because it breaks up the shipping and strews the wreckage along the surrounding shores. This mistral is less violent after the snow has cast its white mantle over the lofty crests of northern Africa, the divergence of temperature being then less considerable than at other times.

On various parts of the coasts of Spain, Italy, Greece, and Asia Minor winds of the same kind, known under other names, sweep in the same manner down from the summits of the surrounding coast ranges. In the depression developed between the Corbières and the Montagne Noire it takes the name of *cers*, the *circius* of the Gallo-Romans, which has at all times been justly dreaded.

CHAPTER XXXIII.

ZONE OF VARIABLE WINDS.—STRUGGLE OF OPPOSING WINDS.—MEAN DIRECTION OF THE ATMOSPHERIC CURRENTS.—LAW OF GYRATION.

BEYOND the changing limits where the trade-winds of the two hemispheres blow, commence the zones of variable winds. There the masses of air flow now in one direction, now in another, and apparently in a very irregular fashion. Sometimes a single wind directs itself incessantly during whole weeks towards one point of the horizon; sometimes the atmospheric currents which succeed each other make the tour of the compass in a few hours; at other times, again, the air remains calm between two meteorological regions where the winds move in opposite directions. Indeed, the word *weathercock* has become a synonym of all that is unstable and versatile.

Even in close proximity to each other two vanes give different indications, because the winds have always a tendency to break into fine narrow currents, complicated with eddies and vortices. A half-decayed tree will sometimes resist a breeze by which a neighbouring trunk of vigorous growth has been blown down.

That which contributes to this disorder of the air in Europe, and in the other lands which are outside the zone of the trade-winds, is the inequality of the ground. The general currents which pass above a chain of mountains do not blow with the same regularity as in the plain. In fact, the winds must be all the more unequal in their successive gusts, the less even is the surface over which they blow. The same wind which moves over the seas with the uniformity of an immense river, departs from its regular pace as soon as it is interrupted in its course by inequalities of the soil. At the foot of the grand mountains of Switzerland, and especially in the environs of Geneva, where the surface relief is already very varied, the alternations which are produced in the force of the wind are such that the anemometer sometimes indicates a variation of intensity from single to triple. In the high gorges of the Alps it often happens, even during violent tempests, that the atmosphere presents at intervals the most perfect calm. To all the furies of the tempest there succeed for an instant silence and repose, then the hurricane recommences to blow with great violence. This is because the atmospheric currents, similar in this respect to the rivers of the ocean, do not direct themselves invariably towards the same point of the horizon, and move by successive oscillations now to the right, now to the left, of the axis of their movement. In consequence, when we find ourselves placed on a point in the mountains which commands a view of the highest peaks, we must, according to the various directions which the aërial current takes, be by turns exposed to the fury of the tempest, or protected by some high summit

on which the force of the wind is broken. Even in countries but slightly varied in surface, or over plains covered with houses and woods, the wind does not blow in equal manner, like the trade-wind of the seas. It advances by a series of gusts and blasts, each one of which represents a victory of the atmospheric current over an obstacle on the plain. Close to the ground the wind is always intermittent, while in the heights of the air it proceeds almost always with an equal and majestic movement like the current of a river. During the recent voyage of the *Magicienne* it was ascertained that at 20 feet above the sea the force of the gale is on an average one-sixth less than when it blows at an elevation of 120 feet. Hence the great importance of topsails for swift-sailing craft. According to the observations made by Secchi at the Collegio Romano, the general average of velocity is about 120 miles in twenty-four hours; consequently a given current might sweep round the globe in 200 days. Although this velocity varies little from month to month, nevertheless it reaches a maximum in the month of March and a minimum in September. As a rule the breeze acquires its greatest velocity between two and four o'clock in the afternoon.

The sudden gusts of the lower strata of this ocean are thus only secondary phenomena, and in all the sudden turns of the winds which one might easily believe to have occurred by chance, the disorder is more apparent than real. Though the wind makes itself felt by turns from every part of the horizon, there, nevertheless, exist only two atmospheric currents in each of the temperate zones: that which comes from the pole to replace the expanded air of tropical regions, and that which flows back from the equator after being raised in the heights of space above the stratum of the trade-winds. In the northern hemisphere these two winds set out, one from the north, the other from the south; but in consequence of the rotatory movement of the earth, their direction is gradually changed, like that of the trade-winds. The wind from the north changes into a wind from the north-east, while the wind from the south ends by blowing from the south-east. Thus, as Dove remarks, the greater part of the aërial currents deceive the observer, because they do not come from the regions whence they appear to blow. The wind from the north-east is in reality much more the wind from the north than the mass of air whose direction is truly southern; in the same way, the wind from the south-east is truly the south wind, and that which seems to come from the south has the south-east as a starting-point.

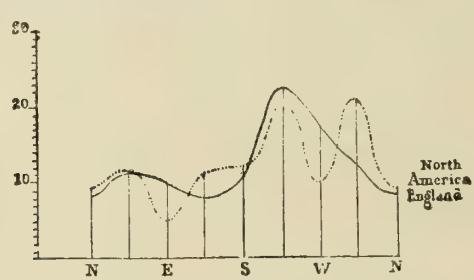
Two great aërial currents thus dispute the extent of each terrestrial hemisphere from the pole to one of the tropics. Generally, all this space is divided into vast oblique bands, composed of masses of air flowing in opposite ways, some from the pole, and others from the equatorial regions. The bands move over the circumference of the globe, and in the same space it is now the polar wind, and now the tropical wind, which prevails. But a compensation never fails to be effected between these atmospheric currents, and the wind neutralised or repulsed in one part of the hemisphere soon makes itself felt at another point. While the strife exists between two masses of air animated by contrary movements, the vicissitudes of the conflict and the gradual preponderance of one of the winds result in temporarily modifying the direction of the air, and making the weathercock turn successively to the various points of the horizon. It is from the meeting of two regular winds that the apparent irregularity of all the atmospheric systems results.

Though the strife between the two aërial streams, now at one point, now at another, does not cease, they are not, however, equal in force, and one of them always finishes by gaining the victory after a longer or shorter period of resistance.

This wind of superior force is the returning current, descending from the heights of space to reach the level of the ground beyond the zone of the trade-winds. In fact, it is evident that in its circuit round the planet any one stratum of air must be much more expanded when it repairs from the torrid zone to the frozen regions, than it is on its return from the pole, after having been condensed by the cold; it occupies thus, in consequence of its temperature, a much greater space in the first journey. This is not all; the vapours with which the air of the equatorial zone is loaded contribute to expand it still more, while the polar winds are relatively dry, and, consequently, much more dense. Thus the winds which come from the tropical zone, that is to say, the south-west winds in the northern hemisphere, and those from the north-west in the southern hemisphere, must have the preponderance, and blow during a more considerable space of time. It is thus at least in the temperate zone of the north, where the winds which are directed towards the northern pole gain the victory, on an average, over the opposing winds.

As the atmospheric currents coming from the equator bend naturally towards the east, it follows that in the northern hemisphere most of the winds blow from the west. This is what we observe in North America, as well as in England. On the Atlantic coasts of France, the proportion between the winds which balance themselves around the western wind, and those which blow from directly contrary

Fig. 107.—General Direction of Winds in England and North America. The Total Duration of the Atmospheric Currents for the Year is represented by 100.



points of the horizon, is about three to two. The proportion would be much more favourable to the former if the chain of the Pyrenees, erected like a high barrier at the south of France, did not modify the direction of the atmospheric currents, and force them to make a detour by the Bay of Biscay, to bend again towards the east. At Cherbourg, in the open Channel, the difference between the winds from the west and those from the east is much greater. According to M. Liais, it is as seven to three. In the valley of the Saone and Rhone, the general movement of the winds is from north to south, as if the air were obliged to plunge in the kind of funnel formed by the Vosges, the Jura, and the Alps to the east; the heights of the Côte d'Or, Beaujolais, and the Cevennes, to the west. It is the same with every secondary valley. Thus the people of Valais scarcely know any winds but those from the east and west; in the high valley of the Rhone, the only winds which make themselves felt are those from the north and south.

According to Kämtz, the mean direction of the wind in the whole of France is S. 88° W., that is to say, that the resultant of all the currents would blow from a point in the horizon situated at two degrees to the south of west. This direction of the wind explains perfectly why the large towns in France and the neighbouring countries tend in general to increase on the side of the west; they seek to breathe pure air. It is for this reason that the rich inhabitants of the great cities migrate,

from generation to generation, towards those portions of the suburbs which look towards the setting sun.

It is a remarkable fact, that the winds from the south-west increase in intensity in proportion as they approach the pole, while the winds from the north-east diminish gradually in force as they approach nearer the equator. The phenomenon is easily understood. The space traversed by the masses of air coming from the south is gradually restricted in the direction of the pole, and consequently the flow of the whole aërial river cannot be effected save by an acceleration of speed. The polar winds, on their side, traverse latitudes where the space opens wider and

Fig. 108.—Map showing the General Direction of Winds in France.

wider before them, and their force slackens gradually to the tropical zone, where they become the peaceful and regular currents of trade-winds.

Already, for some centuries, savants have ascertained that, in the northern hemisphere, the succession of the winds is accomplished in a normal manner in the direction from south-west to north-east by the west and north, and from the north-east to the south-west by the east and south ; this is a rotatory movement similar to that which the sun seems to describe in the heavens, when, after having risen in the east, it proceeds towards the west, developing its vast curve around the zenith. Aristotle made this observation more than two thousand years ago in his *Meteorology*: "When a wind ceases to blow, and gives place to another wind of a neighbouring direction, the change takes place according to the path of the sun." Since the time of the great Greek naturalist many authors, whom Dove has taken the

trouble to enumerate, have re-affirmed this fact of the regular rotation of the winds, which was besides known to sailors from time immemorial.

> "When the wind veers against the sun,
> Trust it not, for back it will run,"

is a seaman's adage. Nevertheless it is only in the nineteenth century that this meteorological phenomenon has been put beyond all doubt. Dove was the first to combine the scattered testimonies which confirm the popular idea, and transform the ancient hypothesis into a scientific certainty. For the future, it has become an incontestable fact, thanks to the savant of Berlin, that in the northern hemisphere the winds succeed each other most frequently in a regular order, which is indicated by the following formula:

S.W., W., N.W., N., N.E., E., S.E., S., S.W.

In the southern hemisphere the normal rotation of the aërial currents is accomplished in the opposite direction; that is to say, from north-west to south-east by the west and south, and from the south-east to north-west by the east and north:

N.W., W., S.W., S., S.E., E., N.E., N., N.W.

Thus in each of the opposite hemispheres the procession of the winds coincides with the apparent path of the sun, which for Europeans describes its daily course to the south of the zenith, and for the Australians passes to the north of this same point. Such is the regular order to which the discoverer has given the name of "law of gyration," and which is often and very justly designated by the name of "Dove's law." Thus the general winds themselves follow, in their succession, the same order as the little diurnal breeze caused by the relative position of the earth and the sun; and it is perhaps owing to the support of these light breezes that the normal condition of the rotation of the aërial currents is established in space.

It is shown, by a great number of observations made in different parts of Europe, that the complete revolutions of the winds in the normal direction are much more numerous than those that occur in a retrograde direction. At Liverpool, London, Brussels, and Kharkov, the direct revolutions constitute, on an average, two-thirds of the total revolutions; in this respect, there is an almost perfect agreement between the atmospheric system of western and that of eastern Europe. In studying the partial revolutions, one does not always arrive at an analogous result, because the direction of an atmospheric current often oscillates to the right and left of one point in the horizon, before describing a complete rotation in one direction or the other. Nevertheless, in order to guard oneself against all errors, it is important to study assiduously all the oscillations of the weathercock, for if such a complete gyration of the wind is not effected in the space of one month, the other kind can be completed in the space of a day. At Gnadenfeld, in Silesia, Kolbing observed a normal rotation, the duration of which did not exceed 16 hours, which is the length of a winter night.

Nevertheless Buys-Ballot has shown that this law of rotation is a secondary fact, depending on the general movement of storms from west to east. In the European temperate zone most hurricanes coming from America have their centre of barometric depression to the north of observers in England, France, or Germany, and the winds rushing towards this centre are brought within the influence of the general meteoric movement. It follows that the winds blow at first from the south-east relatively to the observer, then from the south, and lastly from the south-west in the direction indicated by Dove.

Speaking of the progressive movement of great storms, Elias Loomis remarks that in front of the storm the air appears to be drawn in toward the centre, by which means the pressure on the front side of the storm is diminished. The air, thus drawn in toward the centre, rises to a considerable elevation above the surface of the earth, and its vapour is condensed. In the rear of the storm, the exterior air rushes in and restores the pressure on that side; and as the result of this double process, the point of least barometric pressure is carried forward. This movement of the exterior air in the rear of a storm is not necessarily in the same direction as that in which the storm centre advances. In the United States storms almost invariably advance eastward, and generally toward a point a little north of east; but the wind which presses upon the rear generally comes from the north or north-west, which direction is often at right angles, or nearly at right angles, with the direction in which the storm centre advances. This movement of the air, by which the centre of least pressure is carried forward, bears some analogy to the movements which cause the advance of a wave upon the surface of the ocean, and hence we may with propriety say that the progressive move of a storm area is the movement of a great atmospheric *wave.*

Beside these general considerations, there are various special phenomena which indicate that the movement of areas of low pressure cannot be fully explained by the theory of a general drift of the atmosphere. We frequently find two neighbouring low areas advancing in directions inclined to each other at an angle of 45 degrees, or even a greater angle. In the United States, while a low centre is advancing from Florida along the Atlantic coast toward the north-east, another low centre may be advancing eastward over the region of the Great Lakes, and the two low centres may coalesce somewhere in the neighbourhood of Nova Scotia or Newfoundland. The storms which proceed from the Gulf of Mexico and from the neighbourhood of the West India Islands, generally advance toward Newfoundland; and the storms which come from the north-western part of the United States also tend toward the same region. Newfoundland becomes thus a point of convergence of storm tracks proceeding from regions quite remote from each other. In the vicinity of Newfoundland there exists some influence which appears to act as an attractive force upon storm centres. This influence probably results from the great amount of precipitation near that island, arising from the proximity of the warm water of the Gulf Stream to the colder air from the land. There are other points toward which storm tracks seem to converge, particularly the Asiatic coast near Japan, and this fact probably results from a cause similar to the one just named. Along these converging storm paths, two storms often travel simultaneously and coalesce in a single storm area. Such a movement appears inconsistent with the drift theory.

If we reject the drift theory, it will doubtless be asked how can we explain the fact that in the middle latitudes, storms almost invariably advance toward the east. and the opposite movement only occurs occasionally, and seldom continues longer than one or two days? This fact seems to result from the prevalent movement of the wind towards the east. The result, however, is not due to a general drifting of the mass of the atmosphere within which the low area is formed; but to the fact that the pressure on the west side of the low area is more steady and persistent than that on the east side. The characteristic features of a great storm movement are a motion of the air from all sides spirally inward, together with an upward movement resulting in the condensation of vapour at various places within the low area. Now if the air pressed in with equal force on all sides of the low centre,

and if there was an equal precipitation of vapour on all sides, there does not appear to be any reason why the low centre should advance at all. It sometimes happens that the pressure on the west side is very small, while there is considerable pressure on the east side, and in such cases the low centre moves toward the west. Many examples of this kind are shown by the Signal Service maps, and also by Hoffmeyer's charts. But this movement toward the west cannot be long maintained. In the middle latitudes, the east winds are exceptional, and result mainly from disturbances caused by storms. On the contrary, the west winds result from general causes which are permanent in their character, and are independent of storms; and if there were no storms the west winds would rarely be interrupted. During the prevalence of an east wind, the causes which produce west winds are not destroyed; their influence is only temporarily suspended, and they soon return with a force not impaired, but rather augmented, by their temporary suspension. The pressure on the west side of storm areas is thus a strong and persistent one, while that on the east side results from temporary causes and cannot be long maintained.

CHAPTER XXXIV.

AËRIAL EDDIES.—CYCLONES OF THE EQUATORIAL REGIONS.—THE "GREAT HURRICANE."

THE thunderstorms, which by their sudden violence and vivid flashes of lightning so powerfully impress the mind of man, and which hold such a conspicuous place in all mythological systems, are nevertheless very secondary phenomena compared with the great aërial movements which are manifested in hurricanes, and which give a rotatory motion to the atmosphere for distances of hundreds and even thousands of miles.

It is probable that the wind is never propagated in a straight line. If it were it would be because it did not meet, in its course, any salient points of the surface of the earth, nor strike against any other masses of air, either at rest or moving in opposite directions. The atmospheric currents having always to strive against obstacles of this nature, must necessarily rebound to right or left, and advance by a series of eddies similar to those which the waters of a river form at the meeting of two currents. It is thus that a sudden wind raises the dust from the high road, or drives before it the leaves of the forest. In the same way, during the winter days, when unequal breezes chase each other in the atmosphere, the flakes of snow, in descending, describe long spirals, and the smoke which rises unrolls itself in circles of an ever-increasing diameter. The particles of air, like the heavenly bodies themselves, revolve as they move. If two gusts of air meet at the entrance of a valley, and are continued in long eddies, the circular movement is continued from place to place, like a wave on the surface of the water, and the entire aërial mass is disturbed in its equilibrium.

In all the regions of the atmosphere, where two currents strike one another directly, or come in contact laterally, aërial eddies are instantly produced on the line of meeting, which move with extreme rapidity, and their vast whirls soon re-establish the equilibrium between the two masses of air. When these eddies have only a local importance they are known under the name of whirlwinds, but when their effects are felt over a great extent of country, the more general and more scientific designation of cyclone, proposed by Piddington, is employed. This term can be equally applied to the hurricanes (in Caribbean, *aracan*, *huiranvucan*) of the West Indies, to the *tornados* of the coasts of Africa, to the typhoons (ti-foong) of the Chinese Seas, to the revolving tempests of the Indian Ocean, and to the great gales of Western Europe. Still, we principally designate by the name of cyclone those whirlwinds which are developed according to a regular curve, either in the sea of the Antilles, or in the Indian Ocean, or more rarely in the Pacific Ocean.

Meteorologists have ascertained that the revolving tempests of the equatorial regions occur especially at the time of the reversal of the regular winds. Poey tells us that out of 365 hurricanes which have blown in the West Indies from 1493 to 1885, 245 (more than two-thirds) have taken place in October, that is to say, during the months when the strongly heated coasts of South America begin to attract towards themselves the colder and denser air of the northern continent. In the Indian Ocean it is principally towards the vernal equinox, at the time of the change of the monsoons, and after the great heat of the summer, that the cyclones are most numerous. In the list of hurricanes in the southern hemisphere drawn up by Piddington and completed by Bridet, not a single cyclone is mentioned for the months of July and August; more than three-fifths of these phenomena have taken place during the three first months of the year. It is at this epoch of the change of the seasons that the powerful aërial masses, charged with electricity, engage in strife for the supremacy, and by their encounter produce those great eddies which are developed in spirals across the seas and the continents. Still the whirlwind never occupies in height more than a small part of the atmosphere. According to Bridet the mean height of the hurricanes of the Indian Ocean is rather less than two miles; and according to Redfield it is very rare that a cyclone would prevail at the same time at the level of the sea and at more than a mile above it. Ordinarily the revolving stratum of air is much less thick; occasionally it is even so thin that the sailors in a ship whirled round by a cyclone see above their heads the blue sky or the stars. Above this storm the winds follow their regular path. But as a rule the rotating atmospheric layers are far less thick. In fact, they are at times so thin that the crews of vessels spinning round in a cyclone often see the azure sky or the stars twinkling above their heads. M. Bouquet de la Grye tested this point by a simple experiment. Filling a vessel with water and spreading a layer of oil over the surface, he caused it to revolve rapidly, when he found that the oil became thinner and thinner, at last breaking up in the centre and gravitating towards the sides of the vessel. He therefore thinks that the clouds, under the influence of the centrifugal force, break up in the same way and accumulate round the edge of the whirlwind. Thus would be explained the clear skies so frequently visible in the centre of cyclones.

These sudden movements of the air are perhaps, after the great volcanic eruptions, the most terrible meteorological phenomena of our planet, and we cannot be astonished that in the mythology of the Hindus, Rudra, the chief of winds and storms, should have ended by becoming, under the name of Siva, the god of destruction and death. Some days before the terrible hurricane is unchained, nature, already gloomy and as if veiled, seems to anticipate a disaster. The little white clouds which float in the heights of air with the counter trade-winds, are hidden under a yellowish or dirty-white vapour; the heavenly bodies are surrounded by vaguely iridescent halos and heavy layers of clouds, which in the evening present the most magnificent shades of purple and gold stretching far over the horizon, and the air is as stifling as if it came from the mouth of some great furnace. The cyclone, which already whirls in the upper regions, gradually approaches the surface of the ground or water. Torn fragments of reddish or black clouds are carried furiously along by the storm which plunges and hurries through space; the column of mercury is wildly agitated in the barometer, and sinks rapidly; the birds assemble, as if to take counsel, then fly swiftly away, so as to escape the tempest that pursues them. Soon a dark mass shows itself in the threatening part of the sky; this mass increases, and spreads itself out, gradually

covering the azure with a veil of a terrible darkness or a blood-coloured hue. This is the cyclone, which falls and takes possession of its empire, twisting its immense spirals around the horizon. The roaring of the sea and skies succeeds to this awful silence.

The progress of the wind experiences much more resistance in the interior of continents than on the seas, but the phenomena which are produced there during hurricanes are not less terrible. Buildings which occur in the path of the storm are razed to their foundations, the waters of rivers are arrested and flow back towards their source, isolated trees are torn up and plough the earth with their roots, the forests bend as if they formed but a single mass, and give to the tempest their broken branches and torn leaves. Even the grass is uprooted, and swept from the ground. Innumerable fragments fly in the track of the hurricane like the waifs carried away by a fluvial or marine current. Ordinarily, the action of electricity is added to the violence of the air in movement, to increase the ravages of the tempest. Sometimes the flashes of lightning are so numerous that they fall in sheets like cascades of fire; the clouds, and even the drops of rain, emit light; the electric tension is so strong that sparks have been seen, says Reid, to dart spontaneously from the body of a negro. An entire forest in St. Vincent's Isle was destroyed without a single trunk having been overthrown. In the same way, on the shores of Lake Constance in Europe, a great number of trees which had remained upright in spite of the storm, were completely stripped of their bark.

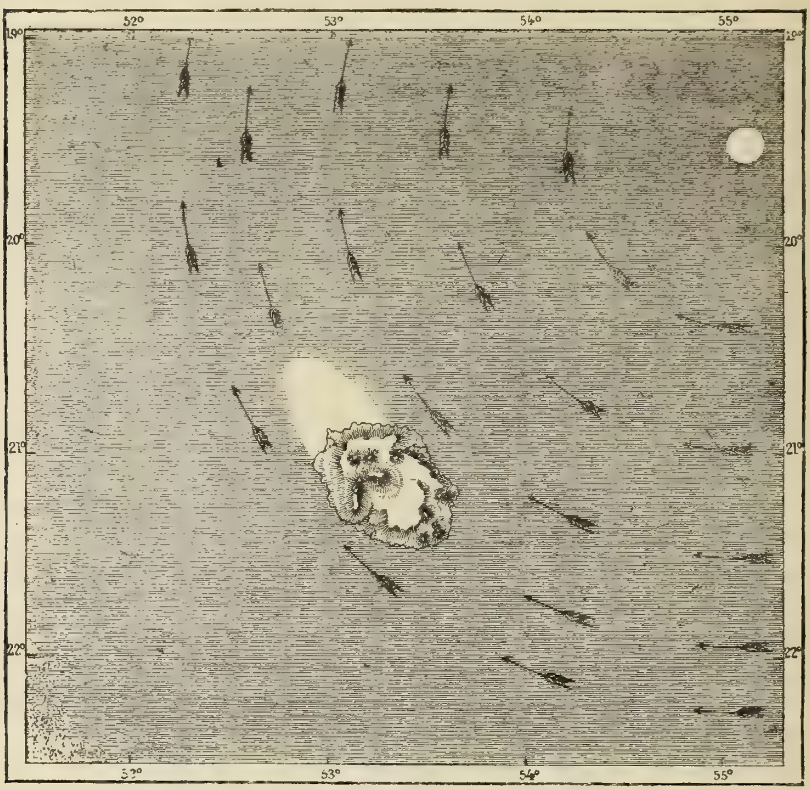
The effects of hurricanes are also felt on the high seas, where they occasionally sweep away whole populations of corals and shoals of fish. In the year 1876, all the east side of the lagune in the Keeling atoll, rendered memorable by the classical researches of Darwin, was changed to a blackish colour after the passage of a whirlwind, by which all the animals had been destroyed. Three years afterwards the bed of the lagune was still blackish, and nothing was visible except a few scattered branches of coral, like so much scrub in the middle of the desert.

It is principally on the shores of islands and continents, where the tempest has not yet been retarded by the obstacles of the ground, that the effects of the storm are the most violent. It is there, too, that the greater number of human lives are destroyed in the general disaster; for then the ships always repair to the ports, and in many places of the coasts there are low lands which the waters, suddenly rising, inundate to a vast extent. Nevertheless, when the cyclone strikes against the mountains of a coast it cannot surmount them, and the regions situated beyond remain completely sheltered. Thus, in the island of Réunion the hurricane only strikes one side of the island at the same time; too low to cross the mountains, it at first only devastates the plains situated on one side; but in its march across the sea the wind doubles the promontory that arrested it, and the ravages are instantly recommenced. Since the time of Columbus, the first European who contemplated the hurricanes of the Antilles, thousands of ships have been swallowed up during the revolving tempests of the tropical seas, either in the depths of the ports and roads, or in the seas that bathe the coasts of America, China, Hindostan, and the islands of the Indian Ocean. Such a cyclone as that of Calcutta in 1864, or of Havanna in 1846, has shattered more than 150 large ships in a few hours; such another catastrophe of the same kind, especially that which passed over the delta of the Ganges in October, 1737, drowned more than 20,000 persons in the rising waters.

In the midst of the ocean the dangers which ships run are less than in badly enclosed roads of the coast; but the sensations experienced by the seamen must be

all the more lively by their being completely isolated and lost in the awful whirlwind. Around them the daylight is darkened, and darker than night one might say, since the little light that still remains serves only to show the gloom. The winds which howl and whistle, the waves which dash against each other, the masts bending and breaking, the groaning of the timbers of the ship—all these numberless sounds are mixed and confused in a terrible despairing wail, drowning even the peals of thunder. The sea no longer rolls in large and mighty waves, but boils over like an enormous cauldron, heated by the fire of submarine volcanoes. The low clouds creeping above the waters often emit a lurid light that one would say was the reflection of some invisible Gehenna; at the zenith appears, surrounded

Fig. 109.—Calm during the Hurricane at Réunion, Feb. 15, 1861.

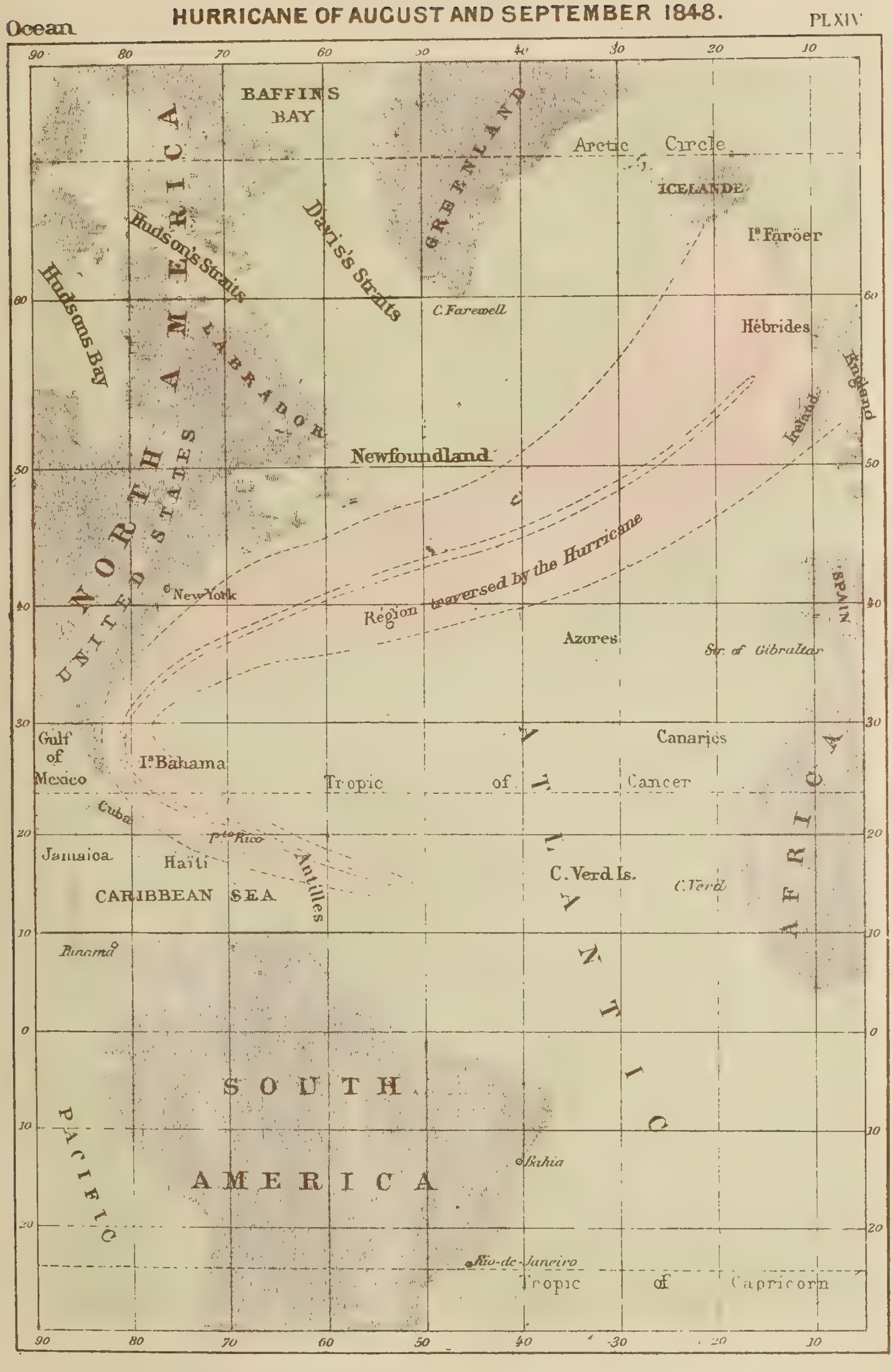


by darkness, a whitish space which sailors have named "the eye of the tempest," as if they really saw a fierce god in the hurricane who descends from the sky to seize and destroy them. When, in the middle of this terrible storm, the sailors accept the strife with the elements, and, defying death, seek to manœuvre and steer their dismantled ship without sails or masts, they certainly furnish a sublime example of human greatness!

Among the effects that certain hurricanes have produced, there are several which would seem quite incredible, if the genius of man could not by means of powder and other fulminating matters impress on the air a still greater rapidity and give it thus, though in very limited spaces, a force of destruction superior to that of the tempest. On the 26th of July, 1825, during the hurricane of Guadeloupe,

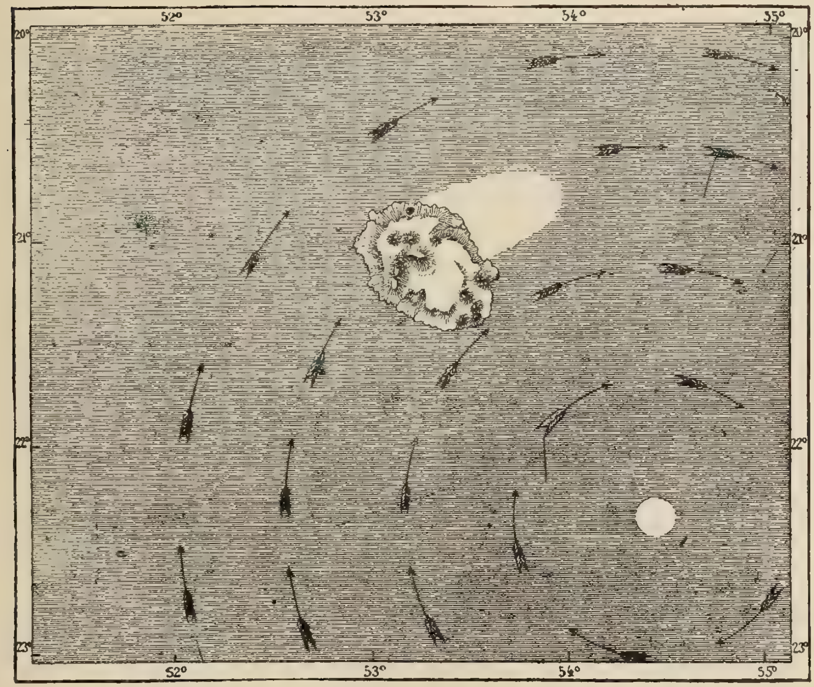
HURRICANE OF AUGUST AND SEPTEMBER 1848.

PL.XIV.



a gust of wind seized a plank an inch thick and sent it through the trunk of a palm-tree 16 inches thick. In the same way, in a lesser whirlwind which passed near Calcutta, a bamboo was hurled through a wall a yard and a half in thickness; that is to say, the breath of air in movement over this point had a force equal to that of a six-pounder. At St. Thomas, in 1837, the fortress which defends the entrance of the port was demolished as if it had been bombarded. Blocks of rock were torn from a depth of 30 or 40 feet beneath the sea and flung on shore. Elsewhere solid houses, torn from their foundations, have glided over the ground as if flying before the tempest. On the banks of the Ganges, on the coasts of the Antilles, and at Charleston, vessels have been seen stranded far from the shore in open plains or in forests. In 1681 a vessel from Antigua was carried up the rocks three yards above the highest tides, and remained like a bridge between two points

Fig. 110.—Calm during the Hurricane at Réunion, Feb. 17, 1761



of rock. In 1825, at the time of the great hurricane of Guadeloupe, the vessels which were in the road of Basse Terre disappeared, and one of the captains happily escaping, related how his brig had been seized by the hurricane and lifted out of the water, so that he had, so to speak, "been shipwrecked in the air." Broken furniture, and a quantity of ruins from the houses of Guadeloupe, were transported to Montserrat, over an arm of the sea 50 miles wide. From the mountains of St. Thomas the immense black whirlwind was seen from afar to pass across the sea and over the islands of Porto-Rico and Santa-Cruz.

The most terrible cyclone of modern times is probably that of the 10th of October, 1780, which has been specially named "the great hurricane." Starting from Barbadoes, where neither trees nor dwellings were left standing, it swept away an English fleet anchored off St. Lucia, and completely ravaged this island,

where 6000 persons were crushed under the ruins. After this, the whirlwind, tending towards Martinique, enveloped a convoy of French transports, and sank more than 40 ships carrying 4000 soldiers; on land the towns of St. Pierre and other places were completely razed by the wind, and 9000 persons perished there. More to the north, Dominique, St. Eustatius, St. Vincent, and Porto-Rico were likewise devastated, and most of the vessels which were on the path of the cyclone foundered with all their crews. Beyond Porto-Rico the tempest bent to the north-east towards the Bermudas, and though its violence had gradually diminished, it sank several English war-ships returning to Europe. At Barbadoes, where the cyclone had commenced its terrible spiral, the wind was unchained with such fury, that the inhabitants hidden in the cellars did not hear their houses falling above their heads; they did not even feel the shocks of earthquake which, according to Rodney, accompanied the storm. The rage of man was arrested before that of nature. The French and English were then at war, and all the ships which the sea swallowed up were laden with soldiers seeking to destroy one another. At the sight of such ruin the hatred of the survivors was calmed. The governor of Martinique caused the English sailors, who had become his prisoners in consequence of the great shipwreck, to be set at liberty, declaring that in the common danger all men should feel as brothers.

CHAPTER XXXV.

SPEED OF THE REVOLVING MASSES OF AIR.—SPEED OF THE CYCLONE.—FALL OF THE BAROMETRIC COLUMN.—IRREGULARITIES OF THE WIND IN THE PATH OF THE CYCLONE.

IT is not yet known what degree of swiftness the masses of air carried by the cyclones can attain, for it is in the upper regions of the atmosphere, where the medium only offers a feeble resistance to the aërial currents, that the storm-wind must have its greatest rapidity. And it does not suffice to ascertain the progress of the particles of air immediately at the level of the ground, or even slightly above it, to form an idea of the speed at which the atmospheric mass carried by the hurricane moves. In one of his ascents Mr. Coxwell made a journey of 68 miles in 60 minutes, while below him the instruments indicated a speed of hardly 14 miles in the same interval. Another time Mr. Glaisher moved at 15 miles per hour, while at the Greenwich Observatory the same sheet of air only advanced 500 yards. How great, then, is the speed of the cyclone at a certain height above the ground when on the earth strewn with obstacles it progresses at the rate of 50 yards per second, or 100 miles per hour, twice the speed of our fastest locomotives! This fearful velocity of the air at the surface of the ocean, and the friction of the aërial particles which results, explains perfectly, as Cicero remarked 1900 years ago, why the temperature of the water rises during storms.

"The rate of progress of the United States storms for thirteen years has been calculated, and the results arranged according to the months, and expressed in miles per hour. The average rate of progress for the year is 28·4 miles, rising to the maximum, 34·2 miles, in February, and falling to the minimum, 22·6 miles, in August. As regards different years, the variation is also much greater in the winter than in the summer months. Thus, in November, 1878, the rate was 21·2 miles per hour, but in the same month of the following year it was 40·7 miles; and, on the other hand, in July, 1882, the rate was 19·8 miles, but in July, 1881, it was 26·6 miles, the difference between the extremes of November being thus 19·5 miles, and in July only 6·8 miles.

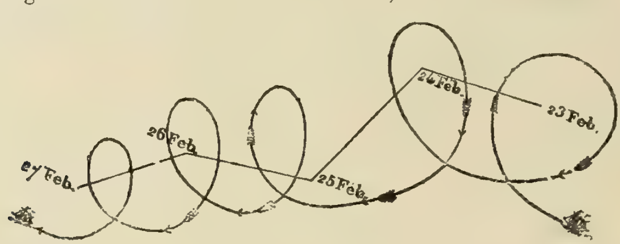
"In Europe, during the five years ending 1880 the mean annual rate of progress was 16·7 miles, rising to the maximum, 19·0 miles, in October, and falling to the minimum, 14·0 miles, in August. Hence the onward movement of storms in the United States is two-thirds greater than in Europe, the rate of excess for the United States over Europe being 1·9 in winter, and 1·5 in summer. On the mean of the year the average onward movement of storms is, in miles per hour, 28·4 for the United States, 18·0 for the middle latitudes of the Atlantic, 16·7 for Europe,

14·7 for the West Indies, and 8·5 for the Bay of Bengal and the China Sea." (*E. Loomis.*)

As to the pressure exercised by the aërial current which moves with such speed, it is truly formidable. In a memoir on the Construction of Lighthouses, Fresnel estimated the strongest pressure of the wind at 616 lbs. per square yard, but it is very probable that in a number of hurricanes this figure has been greatly surpassed. Not to mention the effects produced by the great cyclones of the tropics, a number of cases have presented themselves in the temperate zone where the pressure exercised by the wind on a space of little extent was much greater than meteorologists had foreseen. Thus, to cite but one example, the storm of the 27th of February, 1860, coming from the west, and plunging in the plain of Narbonne by the strait where the canal and railroads of the south pass, was violent enough to force off the rails and partially overturn two trains which it struck cross-ways, between the stations of Salces and Rivesaltes. According to the engineer, Mathieu, who, however, probably gives too high an estimate, the pressure necessary to overturn certain carriages must have been 952 lbs. per square yard of surface.

The masses of air which revolve not far from the central part of the cyclone are the only ones which attain the considerable speed of 60 and 90 miles per hour.

Fig. 111.—Spirals made by the Vessel, "Charles Heddles."



As to the movement of the whole of the storm on the surface of the earth, it is naturally very slow in comparison to the circulatory movement of the aërial particles around their axis. The greatest speed of translation which has been observed is that of the hurricane in the month of August, 1853, which, after having advanced at the rate of 20 miles an hour from the Antilles to the bank of Newfoundland, increased gradually in speed, and ended by exceeding 56 miles an hour. Most of the cyclones of the Antilles move on an average from 12 to 18 miles in the same space of time; but there are some too, especially among the typhoons of China, which advance so slowly that several writers have considered them as revolving on the same spot. At the end of the month of February, 1845, a hurricane which originated near the Mauritius traversed the Indian Ocean with an average speed above 2 miles per hour, while a ship, the *Charles Heddles,* placed at about 56 miles from the axis of the storm, described immense spirals around this changing point. In five days it made five complete revolutions in the midst of the sea, and though in this fantastic voyage it must at least have traversed 1500 miles, nevertheless, when it was finally delivered from the grasp of the cyclone, it was only at 410 miles from the point of departure. The vessel had revolved like a top on the surface of the ocean. According to Bridet, the speed of translation in the hurricanes of the Indian Ocean is comprised between the extremes of one mile and 20 miles an hour.

The movement of the cyclone has the effect of hollowing into a funnel all the central part of the whirlwind, and hurling the masses of air towards the circumference of this enormous wheel which turns in the atmosphere. It is thus that in the rivers, and even the smallest tributaries, the eddies are always depressed in the centre, because of the centrifugal force which carries the waters along in a circle. The diminution of the aërial column makes itself instantly felt by a corresponding diminution of weight, and the mercury sinks in consequence, as soon as the hurricane commences to be formed in the high regions of the atmosphere. The storm which is approaching thus announces its proximity, and those whom it threatens can take their precautions so as to escape entirely from the disaster, or so as to diminish its effects. The sailors whose vessel is anchored in a sure port double their moorings; those who are lying in an open road, exposed to the fury of the winds, as at Réunion, hasten to obey the signal gun, and fly to the open sea so as to withdraw from the centre of the hurricane. The barometer has been seen to fall by $1\frac{1}{2}$, 2, and even $2\frac{3}{4}$ inches—that is to say, nearly a tenth of the total height of the mercury—and each of these perturbations has not failed to be the signal of a storm all the more terrible the higher the barometer had previously risen. At times the rarefaction of the atmosphere is accomplished in such a sudden manner, that the air contained in the houses suddenly expands, explodes, so to say, and hurls windows and doors far away. For this reason, says Fitzroy, the habitations are left open in certain places to avoid such accidents.

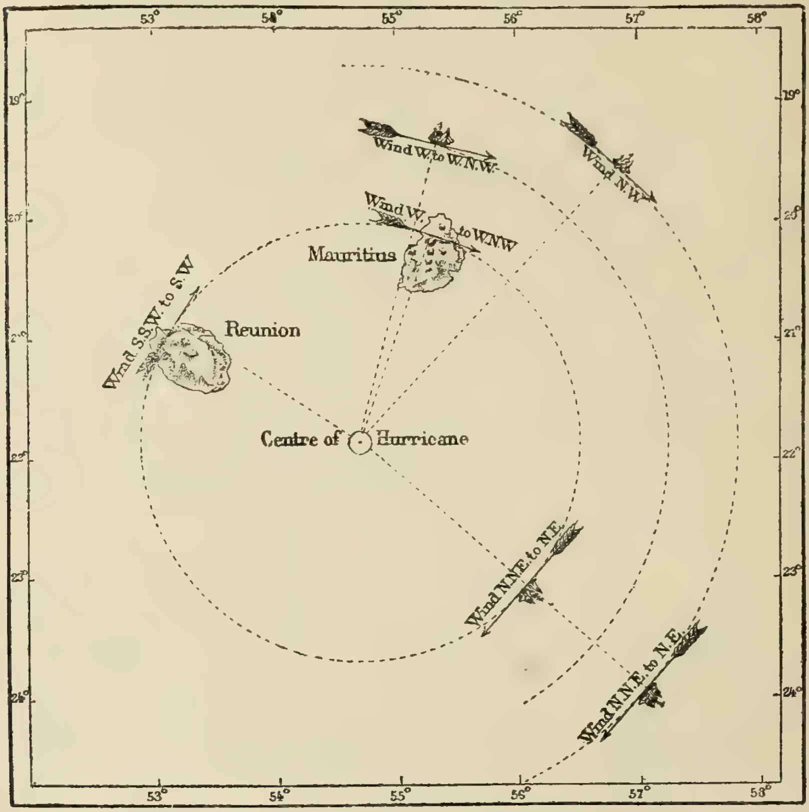
In the sea, the waters rise to a greater or less height in consequence of the lessening of the atmospheric pressure, and move with the centre of the cyclone; thus a "tempest-wave" is raised, whose force is added to that of the formidable surf which the wind has excited. This is the principal cause of those terrible tidal "races," no less dangerous than earthquakes, which roll over the neighbouring coasts. During the hurricane of Barbadoes, in 1831, the waves which broke against the northern promontory of the island were 72 feet higher than the mean level of the water. At the great cyclone of Calcutta, in October, 1864, the Hooghly rose 22 feet all along the lower part of its course, and inundated several islands. More recently still, in the great hurricane which devastated St. Thomas, a wave driven by the wind rushed over the small island of Tortola, committing such ravages that, according to an absurd legend propagated by terror, the entire island was swallowed up. It is certain, too, that the water of the sea can be drawn in in greater or less quantity by the vacuum which is formed in the midst of the whirlwind; this has occurred many times, and especially in Barbadoes. Reid saw showers of salt water fall at a great distance from the shore in the interior of the island, and destroy all the fresh-water fish in the lakes and streams.

The circular movement of the cyclones does not occur indifferently in one direction or the other. Like the regular phenomena of the winds, these terrible storms, as well as all the other great atmospheric perturbations, conform to laws, and their progress can therefore always be foretold by sailors. In the northern hemisphere, the revolving storms of the tropics constantly blow from the south to the north by the east, and from the north to the south by the west; in the southern hemisphere, the path taken by the whirlwinds is in the opposite direction, and the spirals of the wind are uniformly developed by the south, the west, the north, and the east. Such is the law discovered and brought to light by the labours of Reid, Redfield, Piddington, Bridet, and other savants. Thus, winds from all parts of the horizon blow at the same time round the circumference of the cyclone; one ship is pursued by a furious wind from the east, while at 50 miles distant another vessel is

sunk by gales coming from the west. And during all these tumults of warring elements, it sometimes happens that at the very centre of the hurricane the atmosphere remains perfectly calm; a terrible peace, a formidable silence, reigns in the changing circle formed by the raging whirlwind of the tempest.

If the cyclone turned round in its place, the wind would blow exactly in the direction of the tangent over the whole course of the storm; but it is not thus because of the double movement of the hurricane; while revolving it moves on, and consequently the direction of the wind must be the result of the two forces which bear it along. Let the entire whirlwind be directed towards the west, and the normal speed of the wind of the tempest, which blows in the same direction

Fig. 112.—Cyclone in the Indian Ocean, Jan., 1852.

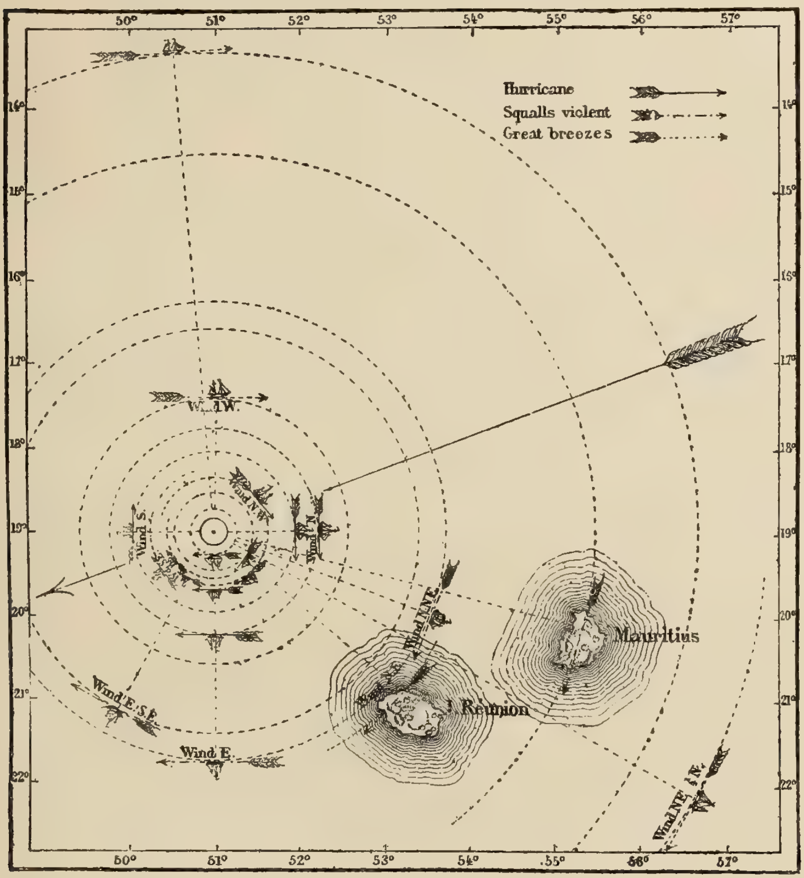


over the periphery of the cyclone, will be augmented by the speed of the storm itself. In return, the wind which will blow towards the east will be partially neutralized, and along all the outline of the circle the direction and the speed will be modified according to proportions rigorously established by calculation. These are the modifications to which the successive winds along the outline of the tempest are subject, and which often render the cyclones difficult to recognize in the regions of the temperate zone, where the speed of rotation of the storms is considerably diminished. Under the tropics, where the whirlwind, being still restricted, is in its primitive force, we remark the less this inequality of these partial winds of the hurricane. It is, however, important enough to be recognized by mariners. One

half of the disc of the tempest is called by them "dangerous semi-circle," and the other "manageable semi-circle." Now, this part of the hurricane, which the great violence of the winds renders dangerous, is always found on the side of the cyclone where the wind proceeds in the same direction as the storm. That half of the disc where the wind adds its own speed to that of the movement of translation is, in the northern hemisphere, to the right of the trajectory of the revolving circle; in the southern hemisphere it is to the left. The accompanying figure gives an idea of the contrast which occurs between the two sides of the hurricane on the path that it traverses in the Indian Ocean.

Speaking of the direction of movement of areas of low pressure, as cyclones are

Fig. 113. Cyclone in the Indian Ocean, Feb., 1860.



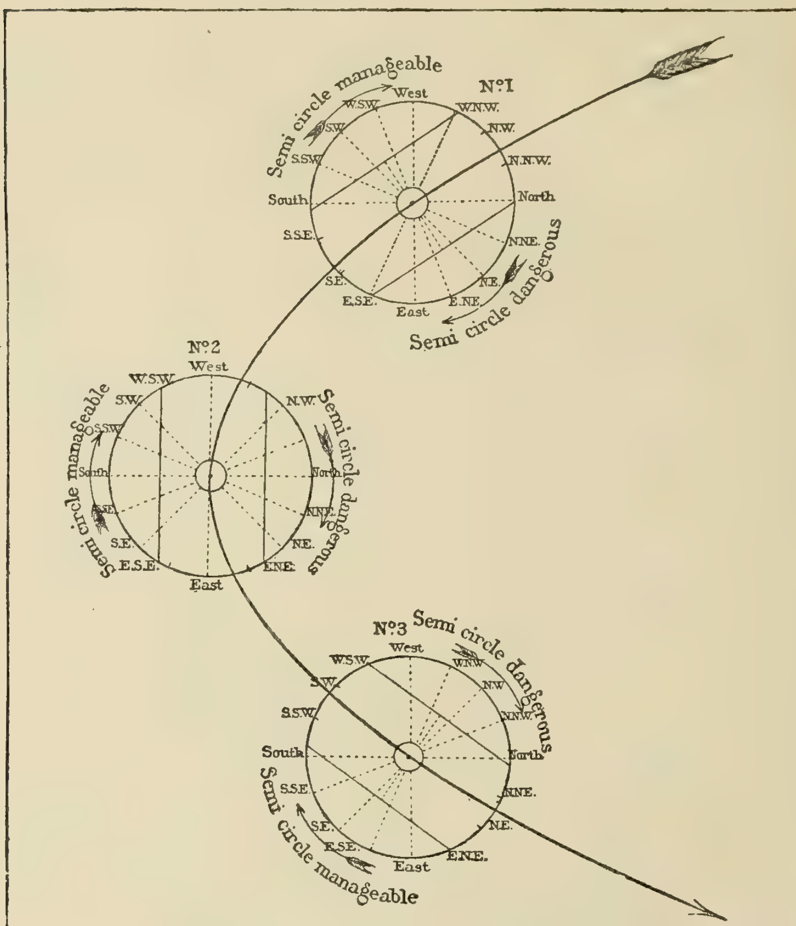
conveniently called, a writer in *Nature* (Nov. 19, 1885), observes that "the centre of low pressure generally changes its position steadily from hour to hour, and everywhere there is observed a marked uniformity in the direction of this movement. Prof. Loomis gives several charts showing the progressive movement of cyclones in different parts of the world, including one showing nearly all the different storm tracks delineated on the International Weather Maps of the United States Signal Service for a period of more than four years. Maury's Storm Charts are also brought under review. The lowest latitude reached by the centre of any cyclone, which has been distinctly traced, is 6 degs. 1 min. north, and there are only eight

cases of cyclones whose paths have been traced to points south of lat. 10 degs. north.

"Observations indicate that, both in the Pacific and Atlantic, gales are of extremely rare occurrence within six degrees of the equator, and, when they do occur, the barometric depression is small, and the cyclonic character of the winds indistinctly marked. But in low latitudes, a little higher than six degrees, gales are more frequent over the Pacific than over the Atlantic Ocean.

"Tropical storms which are found to pursue a westerly course are limited to two

Fig. 114.—Parabola described by a Hurricane (after Bridet).



regions of the globe—viz. the Atlantic Ocean, but particularly its western portion, near the West India Islands, and the region south of the continent of Asia. As regards the Pacific, no cyclone has ever been observed, except near Asia or its outlying islands.

"As regards the tracks of tropical cyclones in the neighbourhood of the West Indies, the teaching of the data represented on the International Charts is that nearly all the areas of low barometer which occur within the tropics and advance westwards, instead of following the ordinary course of the trade winds, advance in a

direction somewhat north of west. Of these West Indian cyclones, 88 per cent occurred in August, September, and October, thus leaving only 12 per cent. for the other nine months of the year. On the other hand, of the Asiatic cyclones 52 per cent. occurred in September, October, and November, and 43 per cent. in April, May, and June, thus leaving only 5 per cent. for the other six months. There is, therefore, a marked seasonal difference as to the frequency of the tropical cyclones of the Atlantic as compared with the Pacific: in the Atlantic they are almost exclusively confined to the autumn, but in the Pacific they are nearly as frequent in spring as in autumn.

"The average direction of the course of the Asiatic cyclones, while moving westward, is 38 degrees north of west, which closely accords with that found for West Indian cyclones. But as regards the onward progress of tropical cyclones, whilst Asiatic cyclones advance westwards at the average rate of 8 English miles per hour, the average velocity of West Indian cyclones is double that amount. Asiatic cyclones veer round to a due north course about lat. 19 degrees 8 north, but West Indian cyclones do not assume a due northerly course till, on the average of instances, lat. 30 degrees north is reached. In the Pacific the average course of cyclones, after turning eastward, was 35 degrees east of north, and their velocity was 9·8 miles, which is scarcely half of the velocity of the West Indian cyclones. These striking and vital differences between the tropical cyclones of the Atlantic and the Pacific will doubtless play no unimportant part in the development of the theory of the cyclone.

"An examination of Prof. Loomis's chart of storm-tracks for the northern hemisphere, with wind charts indicating the prevailing direction of the wind, shows a remarkable correspondence between the two classes of facts. Examining the point more narrowly, Prof. Loomis finds that for the middle region of the Atlantic, near lat. 50 degrees, the average direction of storm paths corresponds very closely with that of the average direction of the wind; but in the western part of the Atlantic the average course of storms is considerably more northerly than that of the wind, while in the eastern part it is more southerly. These results, which fairly accord with those derived from tropical storms, seem to indicate, in the opinion of the author, that in the middle latitudes of the northern hemisphere the direction of progress of storm-centres is not the same as that of the average wind, but is sensibly affected by some other causes; and that the results derived from observations in the China Sea indicate that one of the causes is the prevalent direction of the wind which immediately follows a storm. The subject is further prosecuted by an examination of the prevailing winds and storm-tracks during the three winter months for the ten winters ending 1882 of that portion of the United States between long. 90 degrees west and the Rocky Mountains. The result of this somewhat exhaustive comparison is similar to that derived from the observations on the Atlantic—there being observed no rigorous correspondence between the average direction of the movement of storm-centres and the prevailing wind, but that in some regions the average course of storm-centres is more northerly than that of the wind, and in some regions more southerly.

"While in middle latitudes the generally progressive movement of cyclones is in an easterly direction, cyclone areas are occasionally observed, both in Europe and America, advancing to westward. After a careful investigation of forty-one of the most decided cases which have occurred of these westerly movements of cyclones, it is considered that the following conclusions are warranted—viz. that the westerly movement of low-pressure centres is due to a fall of rain or snow, in most cases usually great, in the region towards which the low centre advances; and the

influence of one low-pressure area acting apparently as an attractive force upon another adjacent low-pressure area; to the influence exerted by two areas of high pressure, not far apart, by which a new movement is imparted to the air included between them, a new low centre being sometimes developed; or to the influence of a high pressure on the north-east side of a low-pressure area, when the gradients on the south-west side of the low area are slight, in which case the centre of the low-pressure area may be crowded towards the south-west."

CHAPTER XXXVI.

SPIRAL OF THE HURRICANES IN THE TWO HEMISPHERES.—THEORY OF CYCLONES. —NAUTICAL INSTRUCTIONS TO AVOID HURRICANES.

AT their departure from the tropical regions, where they fall into collision with the trade-winds, or the monsoons, the greater part of the cyclones of the new world proceed first towards the north-west, parallel to the line of the Antilles, or else along the shores of Columbia and Central America; then, turning back, like a billiard-ball that rebounds in the opposite direction from the impulse received, they follow the coast-line of the United States, describing in the air an orbit corresponding with the course of the Gulf-stream.

In the southern hemisphere the phenomenon is inverted; the cyclones of the Indian Ocean take their origin to the south of Hindostan, and move to the south-west towards Réunion, Mauritius, and Madagascar, then turn abruptly in a south-westerly direction towards the Antarctic seas. The spiral movement of the wind in this great tourbillon is effected from west to east by the north, that is to say, in the same direction as the hands of a watch. The movement is opposite to that which is taken by the hurricanes of the northern hemisphere.

What is the cause of the cyclone itself, and whence comes this sudden change, which occurs in its direction towards the exterior limit of the trade-winds? According to Dove, this is the explanation of these phenomena:—

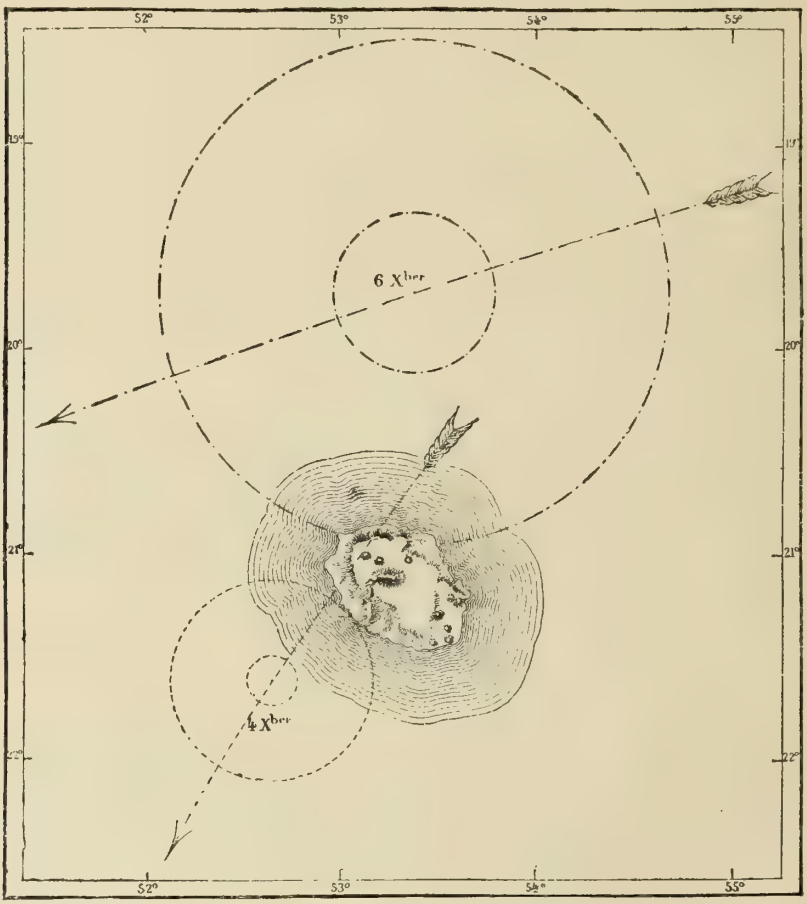
When enormous quantities of warm air ascend over the deserts of Asia and Africa, these expanded aërial masses must spread laterally. Those which are carried over the North Atlantic in a westerly direction, contrary to that of the earth's movement, meet the returning current, which flows from the south-west to the north-east, in the opposite direction of the trade-winds. From this results a conflict between the two atmospheric currents; a whirlwind of air is propagated in spirals in the north-westerly direction, which is the result of the two forces at issue. At the same time the revolving mass descends obliquely towards the surface of the sea, and being compressed to the right by the trade-winds, it continues to advance towards the north-west. Arriving outside the tropics, the hurricane is no longer under the lateral pressure of the north-east wind; it has a free path before it, and under the influence of the earth's rotation, it bends with a graceful curve in a northerly direction, then in that of the north-east. At the same time, the storm which has just entered the temperate zone gradually enlarges the diameter of its spirals, and consequently loses its violence in proportion as it advances towards the pole. Thus the hurricane of 1839, whose breadth was about 300 miles when it crossed the Antilles, extended to 500 miles above the sea of the Bermudas, and

about the 50th degree of north latitude, it occupied no less a space than 1750 miles; but at the same time its destructive effects diminished in proportion to its expansion.

The same wind which has just razed a town in the Antilles, and broken ships like playthings, sometimes contents itself, when it arrives at the Irish coasts, with uprooting a few trees and overturning some already trembling rocks.

Such is the theory proposed by Dove, and which seems the most probable, at least, for the hurricanes of the Atlantic. As to the cyclones of the Indian Ocean, they are, perhaps, produced by the conflict of the south-easterly trade-winds and

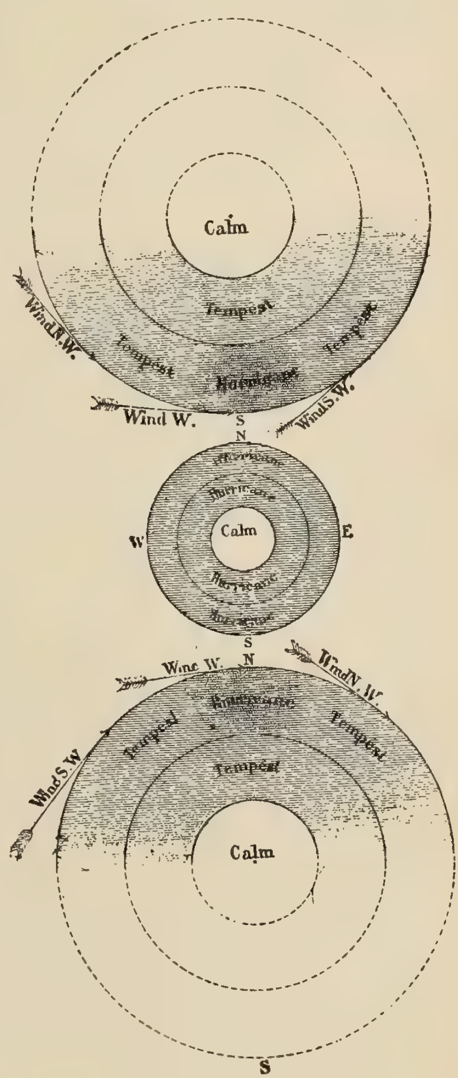
Fig. 115.—Simultaneous Cyclones experienced at Réunion, December, 1824.



the monsoon, which tends towards the continent of Africa. M. Bridet sees in them only the result of the meeting of two winds, one from the equator, the other from the southern hemisphere. That from the equator, participating in the great angular speed of this part of the globe, deviates towards the east, in proportion as it advances towards the tropic of Capricorn; the south wind, carried less rapidly around the earth, deviates, on the contrary, towards the west, and from these two deviations in opposite directions there results, at the meeting of the winds, a revolving movement in the direction from east to west by the south. On an average, the cyclones of the Indian Ocean have a diameter of from 250 to 300 miles in the com-

mencement of their course, from 430 to 560 miles towaras the middle, and from 560 to 700 towards the end; their influence is sometimes felt as far as 1200 miles from the axis of the storm. It is true that two or more cyclones often follow one another at a little distance; lateral eddies accompany the principal whirlwind in the same way as occurs on the surface of the sea; beside the great revolving funnel, formed by the meeting of contrary waters, many circles of the second order are hollowed out. Bridet has collected numerous examples of these simultaneous cyclones.

Fig. 116.—Direction of Cyclones on the Surface of the Earth.



Local obstacles, such as plateaux and mountain-chains, may likewise cause hurricanes, when the aërial masses dash directly against them. Thus, in the Bay of Bengal, at the time of the change from the north-east to the south-west monsoon, the latter strikes against the mountains of Aracan, and in consequence of this shock a sudden cyclone occurs, which turns back towards the north-west, and traverses the whole of Bengal and the northern provinces of Hindostan as far as the Hindu-Kush. It is possible that the typhoons of the Chinese sea owe their origin to similar causes; in this case they would be nothing else than deviating monsoons, transformed into hurricanes, because of the obstacles opposed to them by the mountains of the Philippines and Formosa. Besides all these hilly countries of different sizes and forms, which are scattered over that part of the Pacific Ocean, and are separated from one another by unequal and tortuous straits, cannot fail greatly to disturb the normal condition of the winds, and to produce a great number of storms and hurricanes often confounded under the general name of typhoons. On the other hand, on the Eastern Pacific, where the trade-winds blow with so much regularity, hurricanes properly so-called are very rare. They have only been observed on the eastern coasts of Mexico.

While the cyclone develops its vast curves in the equatorial regions, the entire whirlwind must lean forward, for the upper strata carried away in the hurricane and much less resistance in the air than the lower strata find above the ground and the surface of the sea. The whole of the storm may, therefore, be compared to an immense wheel, revolving horizontally over the globe, and pressing the earth most strongly with its anterior part. Nevertheless, in extending themselves in

large spirals in the two temperate zones of the north and south, the hurricanes become gradually subject to such modifications in opposite directions, and present apparent irregularities so considerable that they seem at first to obey other laws. Instead of leaning forward, one would say, on the contrary, that a real vacuum, incessantly enlarging, was opened on this side of the whirlwind. Thus, as is proved by more than 300,000 observations made in the North Atlantic, on board American, English, and Dutch ships, and carefully compared by Messrs. Andrau and Van Asperen, the winds from the north, which have passed the 30th degree of north latitude, are almost always wanting in the spirals of cyclones. In proportion as the meteor is developed towards the pole, the tranquil zone of the hurricane increases. The winds from the south and from the east diminish by degrees in frequency and in intensity, they then disappear completely. Finally, from the 50th to the 60th degree of latitude the rotation of the cyclone is represented only by winds from the north-west, west, and south-west. One might say that only half the hurricane remains. To the south of the equator similar phenomena occur in inverse order, and every successive curve in the spiral of the storms presents in its southern convexity a greater or smaller break, according to the height of latitude. Fig. 116 may explain the modifications which the cyclones experience while proceeding from the tropical regions towards the poles severally.

The fact that in the northern hemisphere the partial winds of the hurricane are always stronger on the right side of its path, and in the southern hemisphere always stronger on the left, is not sufficient to explain this astonishing contrast between the two halves of the disc of the cyclone. M. Andrau and other Dutch savants have attempted to explain this apparent anomaly. Taken altogether, the hurricane may be considered, they say, as a disc revolving rapidly around its axis. Its natural tendency is to move incessantly in the same plane of rotation, and only the intervention of considerable force can make it incline in one or the other direction. It is true that at the point where it originates over the equatorial seas the cyclone leans more or less strongly towards its source ; but in proportion as it moves towards the pole, revolving round an imaginary axis that remains always parallel to itself, it must necessarily lean more and more backward, in consequence of the curvature of the globe. While the southern part of the hurricane still sweeps over the waves or the plains, the other part rises gradually to a great height in the atmosphere. Soon the upper winds of the tempest no longer make themselves felt at the level of the soil, and are only indicated by the fall of the barometric column and by the clouds which we see hurrying after each other at a great height in the sky. Towards the 50th degree of latitude to the north or south of the equator, the cyclones elevated half-way only touch the earth by the winds of their lower extremity. These winds are the same in the two hemispheres ; they blow equally from the north-west, west, and south-west ; but on each side the gyration is accomplished in the opposite direction.

In connection with this subject an instructive paper was recently read before the Royal Meteorological Society by Mr. Henry Harries, who traced from the North Pacific to the British Islands, the tracks of the typhoon and anticyclone of September and October, 1882. The earliest evidence of the formation of the typhoon was on September 27th, some distance south-east of Manilla. At first the movement was towards north-west, 5 miles an hour, but on September 30th, when the storm-area extended to 1300 miles north-west of the centre, it curved towards north-east, crossed the south eastern corner of Japan at 33 miles an hour, and attained a

maximum rate of 51 miles per hour on October 2nd and 3rd, after leaving the Japanese coast.

In the neighbourhood of the Aleutian Archipelago, the progress was very slow until October 9th, when it rapidly increased to 35 miles an hour, and entered Oregon on the 10th. The Rocky Mountains proved to be no obstacle to the progress of the typhoon, which crossed the range at $36\frac{3}{4}$ miles an hour, and, maintaining this rate, passed across the Northern States into Canada. Thence it crossed Hudson's Bay and Labrador, into Davis Strait. Altering its course to south of east, it passed the southern point of Greenland on October 16th, and two days later, in latitude 55 degrees north, longitude 27 degrees west, it was joined by another disturbance, which seems to have formed about October 9th in 20 degrees north, 48 degrees west. The junction of the two storms was followed by a complete cessation of progressive movement for a week (October 19th to 25th), and it was during this period was formed as a subsidiary the gale which suddenly arrived over our south-eastern counties upon the morning of October 24th, completely upsetting the Meteorological Office forecasts of the previous night. The author quoted several records from ships, which went to show that this secondary storm had not formed until nearly midnight; and that reports from outlying coast-stations would not have enabled successful forecasts to be issued before 3 a.m. on the 24th. The 8 a.m. observations for the Daily Weather Report show that with the exception of Hurst Castle, the winds on the northern side of the Channel were moderate, but along the French coast heavy gales were blowing. Ships' records indicate that off Start Point a moderate easterly gale began at 6.20 a.m. By 8 a.m. a whole gale from S.E. was blowing to the south-west of Portland, while off the Start at 8.30 a.m. the wind veered to W.N.W. a strong gale. At 9 a m. the wind off Portland veered to W. and blew with terrific violence. Farther east, as far as the Downs, the wind had by noon changed to W. and S.W., and increased to a furious storm, with violent squalls and a terrible sea. As this gale passed away the primary moved into the Bay of Biscay and entered France on the 27th. As in Japan and America, its advance was marked by violent gales and destructive floods over a very extensive area—from Algeria northwards. The damage caused by the floods in England was serious, but trifling compared with the losses in Southern and Central Europe, where the destruction was enormous. This typhoon was the principal contributor in making October, 1882, by far the worst within living memory. With this final effort it seemed to have expended its fury, and in crossing France and the Netherlands it gradually filled up. The last trace of the typhoon was in the Baltic on November 1, when it quietly dispersed, after covering over 14,000 nautical miles in thirty-six days, the longest track hitherto followed day by day.

Piddington, Redfield, Bridet, Lartigue, and other learned meteorologists have drawn up rules of general conduct for mariners surprised by hurricanes, which, when they are followed in time, may save the threatened ship. Warned by the barometer of the approach of the cyclone, the captain must be very careful not to fly at full speed before the storm, in the vain hope of escaping the danger. By proceeding in this way, as terror would counsel him, he would rush precisely into the midst of the tempest and expose his ship to all the fury of the wind and the surf. To escape its violence he ought to manœuvre so as to tend obliquely towards the circumference of the storm as far as possible from the central part, where the wind blows with all its force. Unhappily, whatever may be the science of the seaman and his knowledge of the seas which he navigates, it is often very difficult for him to know beforehand from which side the winds will approach, and what is

exactly the orbit which the centre of the cyclone follows across the seas. Nevertheless, if he hesitates too long, he may suddenly find himself within the fatal circle, and be lost, with his ship, from having lacked the necessary boldness. In the high oceanic latitudes it is easier to make a decision, and escape from the cyclone, since the sea is open in the direction of the pole, and the sailor has not to dread being completely enclosed in the midst of a circle of tempests. It is behind him that the lower part of the immense wheel ploughs the waves; before him the ocean is open, or at least the winds which traverse its surface are produced by local causes, and do not belong to the terrible storm. Only at very rare intervals is the upper part of the cyclone brought down to the surface of the water by violent atmospheric counter-currents coming from the polar regions. In thirteen years the Dutch savants have only observed two cases of this nature.

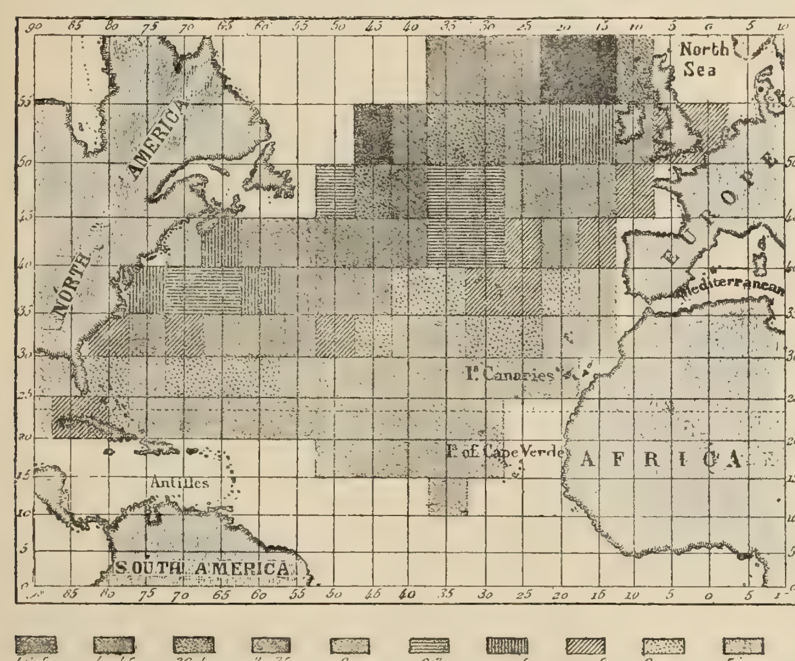
Thus the hurricanes themselves, like the other manifestations of life on our globe, have a regular course, and mathematicians can attempt to calculate the orbit of these terrible phenomena over the face of the earth. It is by conforming to laws and following spirals traced beforehand that the revolving tempests are propelled from the equinoctial zone to the temperate regions. Far from causing by their violent spirals a permanent disturbance in the air, they, on the contrary, only re-establish the equilibrium between the unequal waves of the atmospheric ocean. Still more, they aid conjointly with the monsoons and the counter trade-winds, to maintain the astronomical equilibrium of the planet. Thus, as Dove remarks, the continual friction of the trade-winds, which the terrestrial rotation causes to deviate incessantly towards the west, would doubtless end by retarding the movement of the earth around its axis, if other aerial currents proceeding in an opposite direction did not counterbalance the retarding causes, and accelerate on their part the rotation of the earth from west to east. Slight as may be the breath of wind compared to the force of projection which causes the planet to revolve, it does not the less contribute to the movements of the globe and to its harmonious circles in the concert of the heavenly bodies.

CHAPTER XXXVII

EDDIES OF TEMPESTS.—WHIRLWINDS.

THE atmospheric movements called tempests or gales by seamen differ from the cyclones by their slighter intensity, but are more numerous. In certain parts of the ocean, especially in the North Atlantic, they are so frequent that during some months of the year we may expect a tempest once every two days. This is shown by the accompanying map, every rectangle of which indicates the number of tempests by a different tint. All these gales are propagated in spirals analogous to those of the hurricanes. Storms of winter or tempests of summer originate to the

Fig. 117.—Tempests of the North Atlantic in December, January, and February.

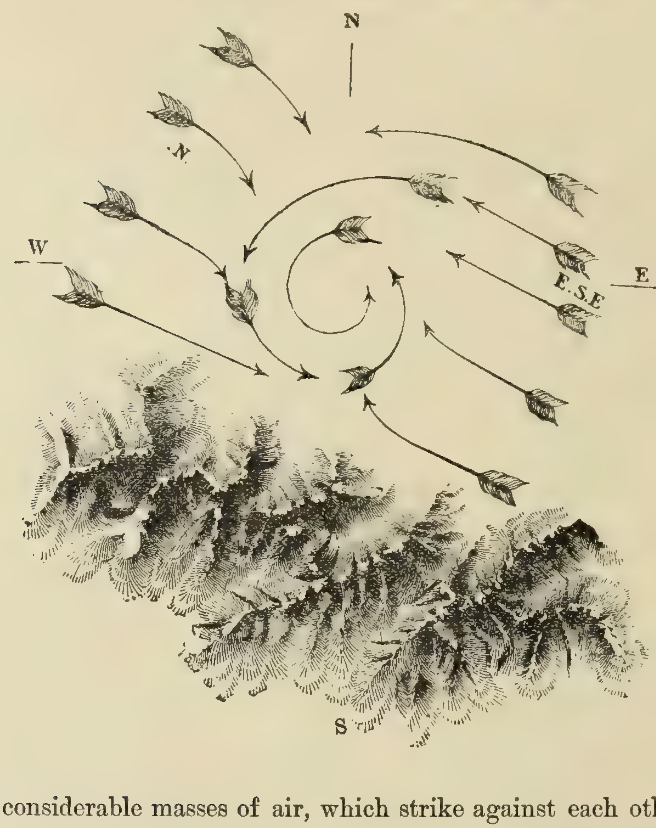


right or left of the Gulf-stream, and are developed in gyrations, caused by the movement of the earth itself. There are likewise local cyclones, revolving only over a single country like France or England, or even in a single valley; we might

cite numerous examples of similar tempests which in a limited space have been scarcely less destructive than the hurricanes of the Antilles. Often when we contemplate the sky above our heads, we see clouds whirling under the influence of two hostile currents and approaching one another only to withdraw again. But it is principally by ascending the side of a mountain that one can witness the curious sight presented by the conflict of two masses of air, which dive into a valley and describe a more or less rapid eddy with their clouds or mists. From the top of the headlands of the Pyrenees the meteorologist Lartigue has observed a great number of these circular winds, similar to the circles which the water of a river describes above a rock.

As to whirlwinds, properly so called, they are phenomena of small importance compared to the cyclones; but, like them, they are due to the encounter of two

Fig. 118.—Storm in the Pyrenees (after Lartigue).



more or less considerable masses of air, which strike against each other obliquely. Still they do not turn invariably in one direction for each hemisphere, for they are not caused, like the hurricanes, by the strife of two regular winds, but may arise from the conflict of all the currents of air, either normal or variable, which traverse the surface of the earth. Observers have seen in the same regions whirlwinds which revolve from the north to the south, some passing by the west and others by the east. During a tempest there may even form on each side of the atmospheric current, as on the shores of a fluvial current, a series of eddies revolving in the contrary direction, and sometimes with sufficient speed to deserve the name of whirlwinds. In the full whirl of the cyclone, the shock of the gusts of wind must likewise produce secondary eddies, moving with extreme speed, now in one direction,

now in another. If it were not so, we should not be able to understand how in the very centre of the hurricane the effects produced by the wind differ in so remarkable a manner in a space of small extent. Thus, according to Reid, it has often been ascertained that during the cyclones of Mauritius lofty houses half in ruins already, were not even shaken by the storm, while solid buildings beside them were completely overthrown and destroyed.

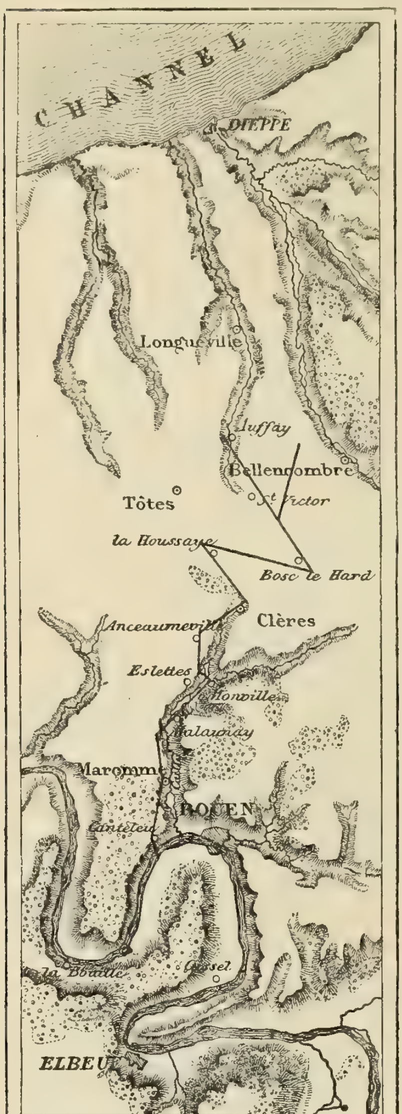
Isolated whirlwinds are sometimes propagated with a rapidity as great as that of the hurricanes, and may cause similar disasters. The whirlwind which passed over Malaunay and Monville on the 19th of August, 1845, was not more than 33 to 44 yards wide in certain places, and in its greatest breadth it hardly attained a third of a mile, notwithstanding which it committed the most terrible ravages,

Fig. 119.—Storm in the Pyrenees (after Lartigue).

and the inhabitants of that part of Normandy long preserved the fearful memory of it. About one o'clock in the afternoon, after an oppressive day, during which the barometric column had suddenly fallen from 29·9 to 27·8 inches, some sailors saw the whirlwind forming over the Seine at the foot of the high cliffs of Canteleu. Like an inverted pyramid, blackish at the base and red at the summit, the whirlwind swept the waters with its point and then rushed into the valley of Maromme. It did not advance in a straight line, nor by elongated curves, but by abrupt deviations to right and left, like the zigzag of lightning. Through the woods which were on its path, it traced wide roads over trees overthrown, shattered, and reduced to ruin; then approaching successively three great silk manufactories of Monville, it twisted them in its spirals, and struck and destroyed them. After having heaped up all these ruins, under which perished hundreds of workmen, the whirlwind

opened an avenue in the ruins on the plateau of Clères, then divided into two branches and ascended into space, carrying with it all kinds of objects, planks, slates, and papers, which fell down again near Dieppe at distances varying from 15 to 24 miles from the place of the catastrophe. It is evident, according to all accounts, that electricity played a very great part in the whirlwind of Monville.

Fig. 120.—Hurricane of Monville.

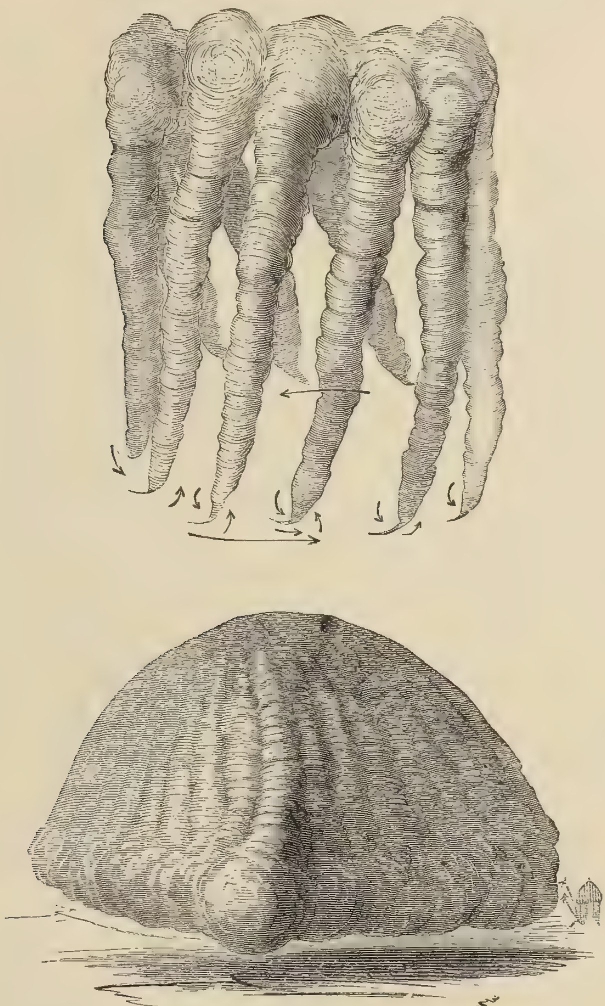


These phenomena, as we can understand, produce different effects according to the region that they traverse. Those which pass over forests break the trees or even twist them in various directions. Others which traverse large prairies, such as the pampas of Buenos Ayres, the steppes of Turkestan, and the grassy countries of Central Africa, raise myriads of locusts in their tourbillons, and carry them either to other parts of the continent, where these insects instantly devour all the crops, or towards the ocean, where they are swallowed up. Sometimes the navigators encounter, at considerable distances from the coast of Africa, real clouds of them, that the tempests have raised from the ground and then consigned to the north-east trade-winds.

In the deserts of the Sahara, Arabia, Khorassan, India, and South America, the winds raise enormous quantities of dust, and cause them to revolve in space. At Buenos Ayres the whirlwinds of 1805 and March, 1866, were powerful enough to render the atmosphere as black as night, and to stifle pedestrians in the streets; after the passage of the storm, the rain which fell showered mud upon the ground. Sometimes the masses of dust are columns revolving and dancing in immense circles like the genii of the air; sometimes, too, they are enormous cupolas whirling in space, covering hundreds and even thousands of yards in breadth, and developing their ellipses for days together and to great distances. These whirlwinds render the atmosphere completely dark and irrespirable. In order not to be stifled, travellers are obliged to shut themselves up in all haste in their tents and to throw themselves down with their faces to the earth, so as to form a rampart of their own bodies against the storm of sand. At the same time the friction of all these grains of dust revolving round one another, disengages in a continuous manner real torrents of electricity. Above the whirlwind large birds of prey wheel in circles, either because they wish to enjoy the atmospheric equilibrium re-established by the storm, or because various small animals which are their food are carried along in the tourbillon.

In mountainous countries the whirlwinds can raise neither clouds of animalculæ nor masses of dust, but they carry into space those heaps of snow so terrible for travellers; more still, they remove even the pebbles and fragments of schist, gneiss, and granite, making them whirl in circles which move rapidly with the conflicting aërial currents. The geologist, Theobald, observed some of these whirlwinds of stones which were no less than from 15 to 20 yards wide; it is not impossible,

Figs. 121, 122.—Whirlwinds of Dust.



therefore, that certain masses of slaty fragments, which resemble piles raised by the hand of man, have been heaped up by whirlwinds.

The marine whirlwinds being phenomena of the same nature as the terrestrial whirlwinds, must likewise raise particles from the surface that they traverse. The foam of the waves is sucked up by the aërial eddy, and ascends with a whirling movement. Sometimes the water swells and rises in great bubbles in the vacuum formed in the midst of the whirlwind by the attraction of the air towards its circumference. In spite of popular accounts, it is very rarely that the water is carried

up to the low clouds which brood over the sea so as to fall in a deluge at a great distance, but the showers of salt water which are discharged far inland during hurricanes prove that this phenomenon is not impossible, and that entire masses of fluid, not merely vapours or scattered drops, can be drawn up into the kind of chimney which the storm makes. It is said that ships threatened by a waterspout have succeeded in destroying with cannon this moving column of vapours and in re-establishing the equilibrium of the atmosphere; but when the waterspout is of considerable dimensions, the passage of a bullet through the whirling vapours can only have very passing results. Besides, a waterspout is rarely an isolated phenomenon; almost always it is connected with a tempest that the vessel cannot escape. Generally, too, the influence of the aërial eddies makes itself felt to a great distance from their apparent limits. Thus the masts of a ship have been broken by the wind when on the deck no violent movement of the atmosphere was perceived, and the tempest still seemed to be distant.

Unfortunately it must be said that the whirlwinds are of all meteoric phenomena those which are least carefully studied. Nevertheless, it is certain that a profound knowledge of the various phenomena which occur in the formation of these slight aërial eddies would enable us better to understand the grander cyclones, the entire system of the winds, and perhaps even the movements of the heavenly bodies, and the rotation of nebulæ. In the same way as embryology has contributed more than any other study to the development of anthropological science, so it is by following from the origin of its movement the particle of air which whirls in space, that we shall be able to explain in a clearer and more precise manner the great facts relative to the circulation of the air, or even to that of the celestial bodies. While the astronomer burns to comprehend some prodigious cycle of the stars, too vast for his eye or his intellect, perhaps there exists under his eyes a simple whirl of leaves or dust, which he disdains even to look at, containing in its spirals the solution of the grand problem.

CHAPTER XXXVIII.

THE VAPOUR OF WATER.—THE MOISTURE OF THE AIR.—ABSOLUTE MOISTURE AND RELATIVE MOISTURE.

THE air which moves and is mingled incessantly at the surface of the earth in breezes or in tempests, in whirlwinds or in cyclones, is at the same time the great agent for distributing the vapour of water. Owing to the movement of exchange which is established from one pole to the other between all the regions of the atmosphere, the water which evaporates from oceans, rivers, and inland lakes, distributes itself over all the countries of the globe, and even over the deserts. While the liquid sea washes only parts of the land, a second sea borne by the atmosphere floats often invisibly over the circumference of the planet.

Above every sheet of water, and even above ice, vapour is always formed, provided that the air be not already saturated; that is to say, that it does not contain exactly the quantity with which it may be mixed without there being a precipitation of moisture. This limit of saturation varies with the temperature. At 4° F. below zero, a cubic yard of air can hardly contain more than 15 grains Troy of vapour; at the temperature of melting ice it cannot receive more than 7 grains of moisture; from 50 to 86° F. the number of grains that it absorbs corresponds nearly to the divisions of the thermometric scale; but above 80 degrees the capacity of air for the vapour of water increases in a much more rapid manner. At 212° F. the atmosphere can absorb its own bulk, the tension of water becomes equal to that of air, and the phenomenon of ebullition is produced; that is to say, the vapour in formation counterbalances all the atmospheric column situated above.

The vapour increases in the atmosphere in proportion to the increase of temperature; such is the true meaning of the vulgar adage which attributes to the sun the power of "pumping up the waters of the sea" to form clouds. Still the same increase of atmospheric heat over two sheets of water of equal temperature does not necessarily produce the same quantity of vapour; the agitation of the air is also one of the most important elements in assisting evaporation. In short, let the atmosphere be perfectly tranquil, and the portion which reposes above the waters will be soon saturated with moisture, and will not be able to absorb any more; but let the aërial bed already charged with vapour be carried away by the wind, and replaced by a new stratum of dry air, this will likewise take its share of humidity, then those which follow will be saturated in their turn; and the phenomenon of evaporation will advance the more rapidly, the more violent the current of air itself is. We know with what speed the dry winds harden the fields

and wet roads; one would say that they lick the ground, so rapidly do all the pools of water disappear.

Hitherto evaporation has been the subject of but few careful experiments, and the attempts of physicists to accurately measure it have generally been made with vessels of too restricted dimensions. In point of fact, the smaller the vessel containing the liquid, the greater appears to be the amount of evaporation. The water in a narrow recipient becomes rapidly heated, its sides being conductors of heat. The wind also, by stirring up ripples on the surface of the fluid, bathes the edge of the vessel and thus increases the space liable to evaporation. Hence it is that, while the ordinary evaporometers indicate for Arles, Orange, or Cavaillon, from 6 to 8 feet a year, according to the different observers, the evaporation of three basins each with a superficial area of 10 square yards and respective depths of 20, 40, and 60 inches, scarcely exceeds 3 feet in the same space of time. The shallower the basin the more active the evaporation in summer; the deeper, the more active in winter.

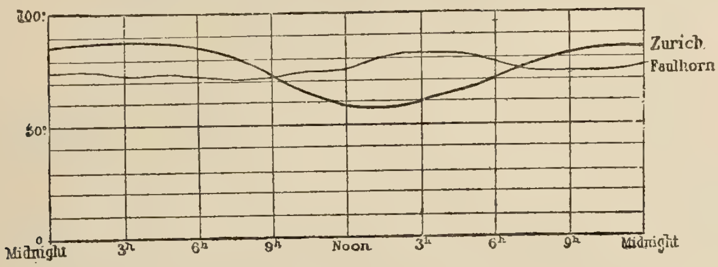
After having thus facilitated evaporation on the sheets of water and moist parts of the continents, the winds transport vapour into the various countries of the earth, and mingle it with dry air, so that nowhere, even at thousands of miles from the ocean, is the air completely destitute of moisture. However, we easily understand that the quantity of vapour is not at equal temperatures distributed in a uniform manner. In open sea the atmosphere is always very near the point of saturation, even when the clouds do not threaten to discharge rain, and consequently the vapour contained in the sea atmosphere diminishes pretty regularly from the equator towards the poles, following the isothermal curves. On the shores bathed by the moist air of the oceans, the proportion of watery vapour diminishes likewise in a normal manner on both sides of the equator. But in the interior of the continents, where the distribution of lakes, rivers, and mountains presents such a great variety, and where the winds follow such different paths, the atmospheric vapour is also distributed very unequally. While the air is almost always either saturated with vapour, or very near the point of saturation, above England and Ireland, in the steppes of Central Asia it is of an extreme dryness, and usually contains only from 15 to 20 per cent. of the vapour which it could absorb. On an average the atmosphere of the continents contains three-fifths of the moisture which it would hold if it were completely saturated in all its extent. This proportion is that which the surface of oceans or basins of evaporation, compared to that of the dry land, would have led us to suppose beforehand.

When the atmosphere contains all the moisture which its temperature can bear, the least particle of supplementary vapour is sufficient to determine the precipitation under the form of drops of a part of the vaporised water; either a mist or cloud is produced, and it begins to rain. Inasmuch as the point of saturation varies in every country and at every season according to the oscillations of heat and cold, it follows that the same quantity of water contained in the atmosphere does not determine the formation of rain at two different temperatures. The same proportion of moisture which, during the winter, completely saturates the cold air, and falls in snow to the ground again, would be very small in the heated atmosphere of summer, and the aërial mass that should contain it would leave an impression of dryness; in the same way a wind, such as the sirocco, for example, would be dry in a warm country like Barbary, and become moist on the cold mountains of the Alps. It is, therefore, important to distinguish clearly between absolute moisture and relative moisture. The first may increase gradually, while the second dimin-

ishes; and though the air would then contain an increasingly greater proportion of atmospheric vapour, it would not the less appear little by little to become drier.

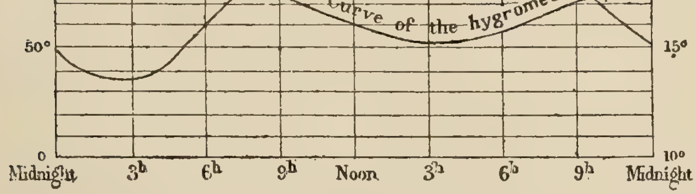
This is, indeed, what takes place every day, as is proved by the long observations of the meteorologist Kämtz. In the morning towards sunrise the temperature of the atmosphere is at its lowest, and it is precisely then, or a little later, because of the vapours from the sun, that the air approaches the point of saturation. In proportion as the heat and absolute moisture increase, the relative moisture

Fig. 123.—Variations in the Hygrometric Degrees at Zurich and Faulhorn.



diminishes, and then rises again when the sun sinks towards the horizon and the temperature falls. Such is the contrast observed in a normal manner in the temperate countries of Western Europe. When the opposite phenomenon presents itself, the cause is due to some great atmospheric disturbance, but the regular oscillations of moisture do not fail to re-establish themselves. The only regions where the air approaches the point of saturation in the warmest hours of the day, are the high peaks towards which the vapours of the plain rise. Thus, while at

Fig. 124.—Comparative States of the Thermometer and Hygrometer at Halle, in July.



Zurich, at the foot of the mountains, the relative moisture is, on an average, much less in the afternoon than in the morning, the exactly contrary phenomenon occurs on the Faulhorn, whose high peak is often enveloped in clouds.

During the various seasons of the year, the successive variations of which reproduce on a larger scale the progress of the day, the absolute moisture and relative moisture present the same contrast as at the corresponding periods of the day; in proportion as the heat increases and the quantity of watery vapour becomes

greater, the air retreats from the point of saturation, and seems in consequence to become drier and drier. This is shown by the accompanying figure borrowed from a work by Kämtz. Still it is necessary to remember that these curves represent only averages, and that in reality the oscillations of the atmospheric vapour are much more complicated. In fact, every variation of temperature, every change of wind, modifies, either by slow gradations or by abrupt shocks, the condition of the air with respect to watery vapour; dryness, moisture, and saturation succeed each other rapidly. Sometimes in a single day one can count a dozen showers and clearings up of the weather. The curves which should then represent the hygrometric state of the atmosphere would be very complicated.

CHAPTER XXXIX.

FORMATION OF MISTS AND CLOUDS.—HEIGHT, THICKNESS, FORM, AND ASPECT OF CLOUDS.

WHEN a mass of air resting on the ground becomes super-saturated with moisture, a certain portion of the vapour is immediately condensed in whitish drops, which by their multitude completely veil or hide all objects, and only allow a dim light to pass through; these innumerable drops constitute mists. They are clouds still attached to the earth and creeping along the plains or up the slopes of mountains. They are formed more especially in the night because of the chilliness of the atmosphere; often we see them rise in the evening from marshy surfaces and damp meadows. When a cold wind descends from the heights of the air, and retains moisture in its lower strata, the mist becomes permanent, and may last for days and even whole weeks. Frequently the sky is pure at a slight elevation above these vapours, and from the top of a summit which rises into free air we may then contemplate at our feet a great white sea, whence the hills spring up here and there like islands.

The clouds properly so called are mists, which, instead of remaining attached to the ground, float suspended in the atmosphere at various heights above the earth. Whence comes it that the vapours imparted to the atmosphere by the surface of the waters mount thus into space? Such is the question which presents itself naturally to all inquiring minds, and which has formed the subject of many mythological fables. The discoveries of modern natural philosophy have resolved this great problem in a general manner. It only remains now to elucidate certain secondary points.

In consequence of the gradual decrease of temperature which the *superposed* aërial strata generally experience on leaving the surface of the ground, the weight of the vapour in the atmosphere is much less in the higher regions than below. It results from this, that the expansive power of the moisture contained in the lower stratum of air is not balanced by the pressure of all the particles lying above it. The vapour from below rises, therefore, to the upper spaces, as a cork to the surface of the sea, till it has at last penetrated into a colder region of air, where it finds itself at its point of saturation, and is condensed in drops. Every cloud that we see in the sky is, therefore, according to Tyndall's expression, only the visible summit of an ascending column of vapour rising into the transparent atmosphere.

The condensed particles of vapour are at first extremely fine; but the air is never in repose, and the drops carried to the right or left by partial currents meet and unite in larger globules. On an average, as the measures taken by Kämtz

confirm, the diameter of the first liquid particles is so small that no less than from 25 to 30 are needed to make ·04 of an inch of thickness. But hundreds and thousands of them driven one against the other unite in smaller or larger drops, and when the drops at last reach the ground they are not less than a ·02 of an inch in size, or even more. While they are still as fine and even lighter than dust, they are the playthings of the aërial currents, which toss them, take them up as they fall, and carry them far away. Clouds of vapour are carried through space as the heavier eddies of sand from the plains very often are. Then when the drops, constantly growing larger by the union of the particles dashed against each other, have become too heavy to allow themselves to be carried along like dust, they fall obliquely to the ground. According to the temperature, the force of the winds, and thickness of the clouds, they are either fine rains, showers, or real deluges.

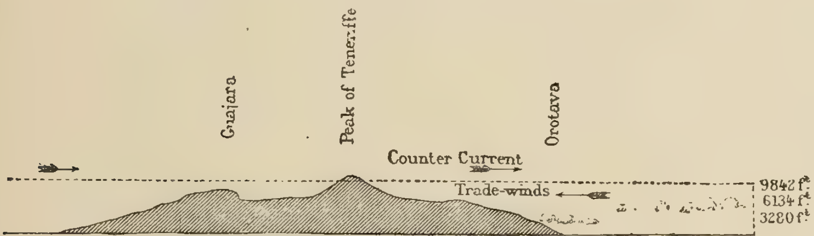
Even when the atmosphere seems to be perfectly calm and no wind is blowing, it often happens that the clouds do not the less remain at a great height, as if they were lighter than the surrounding air. This is because an alternate and continued play of condensation and evaporation is then occurring in the thickness of the clouds and invisible vapours. The drops of rain already formed really fall from the cloud, but in the lower strata not yet saturated they are vaporised again; then mounting a second time towards the colder cloud, they are again condensed there, and in consequence their movement of descent recommences. A perpetual coming and going of particles of vapour visible during their fall, and invisible during their ascent, is thus established on the lower surface of the cloud, which itself changes in dimensions and form, according to the least variations of the temperature. If the heat increases, the cloud will be gradually decreased; if the air becomes a little colder, the haze of drops will increase in volume. There are few sights which exceed in beauty that which is presented by a fine calm summer afternoon with clouds alternately formed and dissolved in the azure of the sky. We first see a simple flake of vapour similar to a white bird floating in space; but this flake grows, spreads, and is surrounded by undecided streamers; it is now a cloud still semi-transparent, allowing us to see the blue of the air through its rifts; then it is a real cloud developing its folds over the arch of the heavens. But let us look a few instants afterwards, and already the cloud is destroyed; perhaps it has divided into numerous fragments which become smaller and smaller, are torn, scattered, melt, and disappear; we think we see them still, but it is an illusion, for the sky has resumed its blue. At other times, on the contrary, the first cloud that we have seen rise does not remain isolated; new masses of vapour are condensed around it, and the space is gradually filled with floating clouds, which approach one another, join, and agglomerate; and soon the sky, which seemed entirely free from vapour, presents in every part a thick stratum of clouds formed on the spot by the chilling of the atmosphere, and the condensation of the particles of moisture.

The height at which the clouds are formed and sustained varies in every season and country, according to the temperature and direction of the winds. There are some, especially among the clouds chased by tempests, which touch the tops of buildings or trees; others float at many hundred yards of elevation; others, again, are level with the highest points of mountains, and all the aeronauts who have passed the summits of the great peaks in their ascents have seen strata of cloud far above their heads. M. Liais estimated a height of 7¼ miles for the most elevated mass of vapours, the dimensions of which he took astronomically. This is an altitude exceeding by nearly two miles that of the highest mountains of the earth, and undoubtedly many clouds mount much higher still in the upper strata

of the atmosphere. As to the mean elevation of the zone where the vapours are condensed, it seems to vary in the countries of Western Europe between $1\frac{1}{4}$ and 2 miles; it would therefore exceed the Vosges and mountains of Auvergne, and would only be overtopped by the ridge of the Pyrenees and the peaks of the Alps. Besides, this zone is necessarily variable because of the changes of temperature; it is higher in summer, and lower in winter.

As to the thickness of the strata of clouds, it is no less various than the height at which the vapours are condensed. There exist clouds of all vertical dimensions, from the thin, transparent veil which allows the light of the stars to pass through, to those enormous masses, superposed in strata 3 miles in thickness, like those that Barral and Bixio traversed in 1850. M. Peytier has found, by 48 measurements taken in the Pyrenees, that the thickness of the cloudy strata was on an average from 490 to 550 yards. According to Piazzi Smyth, this thickness is ordinarily 330 yards round the Island of Teneriffe, where the meteorological phenomena generally present great regularity. Besides, it frequently happens that several layers of clouds mount one above another in the heights of the sky, and the total thickness of the masses of condensed vapour over one point of the earth is thus much augmented. These superposed strata of clouds are often due to the aërial currents and counter-currents which blow in opposite directions at various heights.

Fig. 125.—Winds and Clouds at Teneriffe.



But often, too, when the air is perfectly calm, we see some of these cloudy layers divided vertically in the atmosphere. This is because the lowest stratum, once formed, constitutes for the upper spaces a sort of sea the moisture of which evaporates under the rays of the sun, like that of the ocean or lakes situated below. The moisture changed thus into invisible vapours condenses in the colder air at a certain height, and forms a second stratum of clouds, which in its turn originates a third and more elevated layer.

In consequence of the different causes which give rise to vapours, the clouds assume the most varied appearances over the land, the sea, and even the rivers. It is said that the red men, those sagacious observers of all the phenomena of nature, knew, whilst they yet ranged the central plains of North America, how to recognize from afar the course of the Mississippi by the form of the clouds stretching above the river in elongated strata. Still it is principally round the outline of the islands of the ocean that we can best observe this difference between terrestrial and maritime clouds. At Teneriffe the contrast occurs in the most striking manner. In summer the great white sheet of clouds which the trade-winds carry along, is developed uniformly over all the oceanic spaces. But in calm weather this bed of clouds terminates at a certain distance from the opposite flanks of the peak of Teyde, in a kind of escarpment from 600 to 900 feet high. Within this circle formed by the oceanic clouds the land is surrounded by its own

zone of steaming vapours; these latter, much lower than the larger clouds of the sea, attach themselves to the slopes in long fringes, moved in a very different way from that of the exterior zone, and quite distinct by the colour and form of their folds. Piazzi Smyth, who was able thoroughly to study the phenomena of these various strata for many months, compares the terrestrial clouds of Teneriffe to that of land-ice which is formed around the islands and polar continents, and which constitute a solid platform, while the ice-fields in the open sea are broken by the currents, and carried away in fragments.

Meteorologists have attempted to class the clouds in various categories according to their exterior appearance, but this is a very difficult undertaking, because of the infinite variety of forms, and the extreme mobility of the vapours which float in the sky. However, they have generally adopted Howard's classification, according to which the clouds are referred to three great types, the *cirrus*, the *cumulus*, and the *stratus*, which mingle variously with each other, and thus produce secondary combinations bearing the names of *cirro-cumulus*, *cirro-stratus*, and *cumulo-stratus*. These are, however, for the most part conventional divisions, which every meteorologist can modify at his pleasure, and Fitzroy has added ten varieties to the types and sub-types of clouds indicated by Howard.

The cirri are small white clouds, as fine as carded wool or plumes of feathers; these are the *cats'-tails* of sailors, and are always perceived at a great height in the sky. According to Kämtz, their mean altitude is not less than four miles above the highest mountains and most elevated spaces to which aeronauts have attained. These slender cloudy filaments are still found, most often arranged in parallel rows, in the same direction as the trade-winds or counter trade-winds, which indicates the regularity of the aërial currents in the heights of the atmosphere. The cirri are formed of icy particles, as natural philosophers have been able to ascertain by the luminous phenomena of reflection and refraction which occur in them. When the cirrus sinks and the crystals of ice are melted, the cloud gradually undergoes a modification of appearance, and changes into the cirro-stratus or cirro-cumulus. In the first case, its light whirls are mixed and confused in a cottony or greyish mass, prognostic of approaching rain; in the second the sky is filled with those little dappled clouds, which by contrast give to the blue of the air such a beautiful hue. According to popular legends, these are flocks of sheep grazing in aërial spaces.

The cumulus which seamen distinguish under the name of "cotton bale" is distinguished from the cirrus by its origin no less than by its aspect. Instead of having been brought from very distant regions by the wind, it has generally been formed on the spot by the condensation of ascending columns of vapour. We see this sort of cloud piled on the edge of the horizon, in enormous rolls with clearly defined outlines; one might sometimes think them to be gigantic chains of mountains, whose rounded white summits stand out against the deep azure. Their base is almost always horizontal, and spreads widely in an immense layer, indicating the precise zone of space where the invisible vapours coming from below are condensed into mist. The heavy cumulus, charged with an enormous weight of moisture, never rises to the same height as the cirrus, and hardly exceeds two miles in elevation; the highest which M. Liais measured was at two miles. It mingles variously either with the cirrus or stratus; that is to say, with those bands of clouds disposed in the sky in long sweeps or parallel strata. This form is what the mists most frequently affect on detaching themselves from the ground, but it must be said, also, that clouds in reality most distinct resemble "stratus" when they are seen in perspective on the distant horizon. As to the "nimbus," of which

some meteorologists have wished to make a special type, it is simply a rain-cloud, which is developed in the sky and breaks into showers.

By the marvellous diversity of their forms, clouds are one of the great beauties of the atmosphere. Among all the images, whether fearful or graceful, that the fancy of man can dream of, there is not one which is not to be found in the vapours of space. By their fugitive outlines clouds resemble flights of birds, eagles with outstretched wings, groups of animals, reclining giants, and monsters like those of fable. Other clouds are chains of mountains with snowy summits; others, again, represent immense cities with gilded cupolas. Poets see in these groups distant archipelagos, where the happiness so much sought for, and which does not exist on this earth, is to be found. Superstitious people, often pursued by the terror of their own crimes, see in them bundles of weapons, war-horses, armies in battle-array, and massacres. The light playing in this fantastic world of images increases still more their astonishing variety; all imaginable shades shine over these floating bodies, from snowy whiteness to fiery red; the sun colours them successively with all the graduated tints of dawn, daylight, and sunset; meadows and forests are reflected there in greenish tones, and the sea itself is produced vaguely by a colour of metallic brilliancy recalling that of copper or steel.

CHAPTER XL.

INFLUENCE OF THE WINDS ON THE FORMATION OF SNOW AND RAIN.—DISTRIBUTION OF RAIN OVER PLAINS AND MOUNTAINS.

EVERY aërial stratum containing aqueous vapour to the very point of saturation, must necessarily let fall to the ground a certain quantity of drops, which are the cloud itself. If the air were perfectly calm these precipitations of moisture would always occur in a slow and continuous manner; the earth, enveloped in a constant mist, would, however, never be watered by heavy rains. Nevertheless, in almost all the countries of the world clouds and showers follow fine weather, and fine weather succeeds to rain, owing to the winds which meet in space and mingle air and moisture variously together. They purify the atmosphere from the superabundance of its vapours, and determine the formation of those sudden rains, without which the circulation of the waters and the general movement of life would be much less rapid on the surface of the globe. In fact, when two aërial masses unequally heated come in contact with one another and mingle, the temperature of the warmest suddenly sinks; its capacity for holding vapour diminishes in consequence, and the moisture which it contains must be precipitated in rain. It is true that on its side the coldest wind is warmed and saturated by a greater quantity of vapour. But there is no compensation in this, for the point of saturation in the aërial strata is not exactly proportioned to the temperatures. If the masses mingling assume a mean temperature between the two extremes, on the other hand, the capacity for holding vapour falls relatively below this average. Hence the immediate effect of precipitation which occurs ordinarily at the time of the conflict of the winds, and especially at the mingling of the counter trade-winds, loaded with moisture, and the cold winds coming from the pole. It is then that we see clouds amass themselves so rapidly in the sky and fall suddenly in violent showers. A few hours, sometimes even a few minutes, are sufficient for the blue of the air where the two winds meet to be hidden by the dark folds of storm-clouds.

At the Paris observatory, it has been ascertained that the quantity of rain falling on the terrace of the building at 91 feet high is always less than the quantity of water collected in the courts situated below. This is because, in traversing the atmospheric strata saturated with moisture, each drop enlarges itself on the way by other scattered droplets, and continually brings back to the earth the pluvial moisture which has evaporated. Perhaps, too, we ought to see in this increase of precipitation only a local fact, and attribute it in great part to an eddy of the drops in a kind of funnel formed by the courtyards of the building. At Paris the difference between the respective quantities of rain which fall on the

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terrace and into the court is about 2·4 inches; at the summit of the edifice the annual depth of rain is 19·7 inches, while at the base this depth rises on an average to 22 inches. At Berlin the respective quantities of pluvial rain which fall on the roof and in the courtyard of the observatory are a little less, but the difference is also about a ninth.

Still we must not conclude from these facts that rains are less abundant on the mountains than in the countries lying at their feet. On the contrary, as the densest clouds always float at a considerable height above the low plains, it results from this that the most abundant rains fall on the slopes of the mountains. Driven by the wind, the moist masses strike against the cold rocks standing up across their route, and turn to rain; the ravines and gorges are filled, while the lightened clouds mount the sides and cross the chain of mountains by the passes opening between the summits. This is a phenomenon which we can easily observe from the height of an advanced promontory, when the rain-clouds roll towards the mountains. Even when the lower plains do not receive a drop of rain the sides of the mountains are inundated and the torrents swell. Arriving in blackish or copper-coloured masses, which one would think were solid as rocks or metal, the clouds disappear in light greyish vapours; long after they have passed a transparent mist may be seen hanging to the bushes and tree-tops. This is the superabundant rain which evaporates.

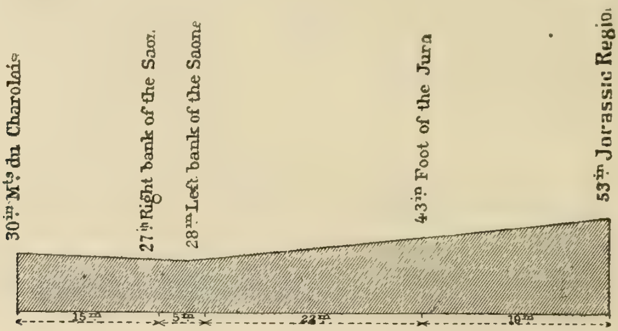
Among the causes which determine a greater precipitation of moisture on the mountains than on the plains below, we must also reckon the difference of temperature usually existing between the summits and the surrounding atmosphere. During the day the slopes exposed to the warmth of the sun are more heated than the surrounding air—at least in calm weather; but the ravines often remain much colder, and consequently the contact causes rain to fall by suddenly chilling the atmospheric strata. During the night, and at all times when the wind blows violently, the salient angles of the mountains become in their turn much colder than the sheltered gorges, and it is they that condense the mists of the air and cause the rain. How many times in mountainous countries, when the sky is perfectly clear and blue, do we not see the high peaks enveloped in a mist like the smoke of volcanoes! These clouds which we perceive around the summits are found in warm air in the state of invisible vapours; it is the cold contact of the rocks or snows which has suddenly revealed them. The mountain peak thus announces to the inhabitants of the valleys that the atmosphere is saturated with vapours, and warns them of an approaching change in the temperature. The mountains thus constantly serve as meteorological indicators to the neighbouring population, and in each mass of heights they always look towards one of the largest peaks, to see if it has "put on its cap" of clouds.

Direct observations collected in various parts of the world have demonstrated that, all other things being equal, the annual precipitation of rain-water is in proportion to the altitude of the country—at least to a certain height in the mountains. According to Keith Johnston, the average rainfall for the plains would be 22·6 inches per year in Europe, and for the mountainous districts about 51 inches; this is about the proportion which is observed in Alsace. In the valley of the Rhine the quantity of rain is on an average from 22 to 22·8 inches in the year, while on the high Vosges it is from 43 to 47 inches. Alsace therefore is in this respect a resumé of the entire continent. The Jura, arresting the passage of the winds which bear the vapour drawn from the ocean, forces them also to let fall their burden of moisture. By tracing a transverse line to the valley of the Saone from the heights of

Charolais to the mountains of Jura, M. Fournet has ascertained that the annual precipitation increases tolerably regularly with the altitude; from 27·4 inches on the right bank of the Saone it increases gradually to the parallel wall of the Jura; on the western side it becomes greater with the altitude, and thus from the height of the ground we could estimate the mean quantity of rain.

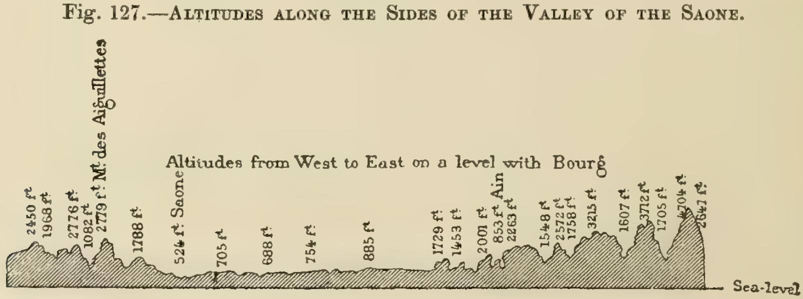
On the southern slope of the Cevennes, where the winds blow with such violence because of the rapid variations of temperature produced by insolation and radiation,

Fig. 126.—Rainfall on Sides of the Valley of the Saone.



the difference which is observed between the annual falls of rain is still more considerable than at the foot of the other mountains of France. Over the town of Arles the total precipitation is 17·7 inches; but at some 60 miles to the north the town of Joyeuse, situated in the valley of Ardèche, which overlooks the mountain rampart of Tanargue, received in 1811 as much as 67·6 inches, and the annual mean is about 51 inches. On the 9th of October, 1827, enormous quantities (28·7 inches) of water fell there in the space of 21 hours; more than falls on an average on the soil of France during a whole year. Hence the formidable inundations of

Fig. 127.—Altitudes along the Sides of the Valley of the Saone.



the Ardèche. To the east, in the valley of the Rhone, which the winds of the Mediterranean are able freely to ascend, the annual fall of rain is always much less.

On that side of the Alps turned towards the plains of Italy analogous phenomena are observed. The mountains which close the Adriatic Gulf on the north receive twice, and in certain valleys even three times, as much rain as the plains of Padua and the lagunes of Venice. But in Europe it is principally on the shores of the ocean, where the west and south-west winds bring such a large quantity of vapour, that the action of mountains or even of simple chains of hills, on the precipitation of moisture, is manifested in all its geological importance. At Lisbon the

annual fall of rain-water is hardly 27·6 inches, while at Coimbra, in a valley indenting the interior, there fall on an average 135 inches of water, more than in most tropical countries. In the same way the little mountains of Westmoreland, placed crossways to the kind of funnel which the Irish Channel forms, receive as much as 150 inches. In exceptional years this enormous quantity of rain-water is much exceeded; and yet Liverpool, situated likewise on the coast of the Irish Sea, receives in the same space of time 34 inches of rain, that is to say, only one-fourth or one-fifth. As to the western coasts of Norway, which rise abruptly out of the sea, they are not exposed to less abundant rains than the hills of Borrowdale and Kendal in Great Britain. At Bergen the annual fall of rain is 105 inches, and undoubtedly other localities, whose fiords constitute real funnels where the wind from the open sea plunges laden with vapours from the Gulf-stream, are watered by a still more considerable quantity of rain.

The countries of the world where the rain falls in the greatest abundance are probably the coasts of Malabar, those of Aracan, and the lower slopes of the Himalayas. There everything favours the quantity of water to be very abundant in the rainy season: tropical heat, an enormous basin of evaporation, and the height and direction of the mountain ramparts, which must retain the clouds, all assist to this

Fig. 128.—Comparative Amounts of Rainfall.

end. The Indian Ocean, an immense cavity in which the waters are incessantly revolving, and the superficial evaporation of which is more active than that of all the other seas in the world, continually supplies the rain-clouds that the monsoon carries now towards the coasts of Africa, now towards those of Asia. There the mountains placed directly across the aërial current, force it to rise over their slopes, and thus to mix with the colder atmospheric strata. A real deluge results from this: black clouds charged with rain let fall their enormous burden, the valleys are inundated, and the torrents changed into rivers.

At Mahabuleshvar, situated at 4461 feet high on the western slope of the Ghauts, the annual average of rain ascertained during a period of 40 years is 275 inches. At Pondicherry at the same altitude, on the Garrow mountains, to the south of the valley of the Brahmapûtra, the quantity of rain discharged annually by the clouds is much greater—it is 550 inches; that is to say, it rains almost as much during the twelve months as at Alexandria during a century; in the single month of July, 1857, as much as 148 inches fell there. It is probable that these enormous rainfalls have been even exceeded in several valleys of the Himalayas, for Thomson and Hooker speak of a locality where the rain is not less than 470 inches in seven months, and where a temporary deluge of four hours, similar to the breaking of a waterspout, covered the ground with a liquid sheet estimated at 30

inches deep. In a single shower, therefore, this valley of the Indus had received proportionately as much water as France receives during a whole year. According to Cleghorn, the average of rain on the coast-lands of India was only 42·5 inches, scarcely the eighth part of that which falls on the mountains of the interior. It is from the enormous precipitation of moisture from the clouds brought by the monsoons, that the base of the first counter-forts of the Himalayas is bordered with the unhealthy zone of the "Teraï," whose jungles travellers are obliged to pass rapidly, so as to escape by dint of speed from fever and death.

Nowhere certainly in other regions of the torrid zone is the precipitation of rain favoured in so remarkable a manner. On the slopes of the Kiliman'jaro it rains almost every day during ten months ; but the traveller, Von der Decken, who was the first to ascertain this meteorological fact, does not say that the rains fall as abundantly as in India. In the Gulf of Guinea the monsoons, which are precipitated towards the continent, meeting with but few mountains that present an obstacle, carry their rains far into the interior of Africa. The Antilles have not enough breadth to hinder the winds and clouds from deviating obliquely to right and left, and the greatest annual quantities of rain that have been ascertained there in the high mountain gorges do not attain 390 inches, which is 160 inches less than at Pondicherry. On the coasts of Columbia the chain of the Andes, relatively but little elevated and here and there interrupted by wide valleys, presents itself obliquely to the direction of the trade-winds; but in the funnel of the Gulf of Uraba and in the almost impenetrable forests of the province of Chaco, the rain falls in truly prodigious quantities, hardly inferior to those of the Himalayas. It is to this enormous precipitation of moisture that the Atrato, a river relatively insignificant by the length of its course, rolls along a quantity of water greater on an average than that of the largest rivers in Europe.

Whatever may be the difference between the rains in various climates, this phenomenon of a greater abundance of rain on the slopes of the mountains than in the plains, is a general fact all over the earth. We observe it in India as in Europe, in Patagonia as in the Antilles. Still we must not conclude from this that the precipitation of moisture increases in an indefinite manner in proportion to the height of the mountains, and that the summits always receive the greatest quantity of water under the form of snow or rain. On the contrary, it is certain that above the zone where the thickest clouds generally float the rain diminishes by degrees. The want of precise observations prevents us from indicating the average height of this zone in the various countries of the world, and consequently we cannot yet determine the laws of distribution of rain in a vertical direction. But methodical researches on the movements of the clouds will little by little furnish all the elements necessary, and will allow us sooner or later to point out on each mountain slope the spot where the greatest quantity of vapour will every year be transformed into water.

In the Alps of Switzerland this zone of the greatest precipitation is tolerably high, for the total bulk of snow-water and rain which falls annually at the Great St. Bernard pass exceeds by more than 39 inches that which is collected at Geneva, at the foot of the mountains. Below it is only 32·5 inches, while on the snowy pass it is on an average 79 inches. Figures are wanting to establish the fact that on other mountain chains the elevated slopes receive a much less quantity of water than do the lower valleys opening half-way up. But this is a phenomenon not the less certain, owing to the researches already made on the mean height of the clouds. As to the mountain slopes which are not struck by the rainy

winds, and the plateaux surrounded by terraces, they only receive in general a very slight proportion of rain, and a number of them are, owing to want of water, transformed into real deserts. The peaks which rise above the atmospheric currents arrest the clouds en route, and only allow dry winds to pass. Thus the plateaux of Castile are only traversed by meagre rivulets, while through every valley of the Cantabrian Pyrenees there flows a pretty considerable river. It is the same in Columbia; on the abrupt coasts which the trade-winds strike against, the mean depth of rain-water is estimated at 81 inches per year, and on the plateaux of the interior it appears to be only 41 inches. At Bogota, in the centre of the plateau of Cundinamarca, it is 43·5 inches, hardly as much as on the high Vosges in the temperate climate of Europe. Finally, the rain which falls on the high plains of the Deccan on the eastern slope of the Ghauts, would be considered insufficient in most countries of Europe, where, however, the evaporation is much less than in Hindostan. At Poonah, situated on the plateau immediately to the east of the mountains which overlook Bombay, the annual fall of rain is only 23·5 inches.

CHAPTER XLI.

TROPICAL RAINS.—RAINY AND DRY SEASONS.—PERIODICITY OF RAINS.

THE form and relief of lands, as well as the situation which they occupy relatively to the extent of ocean, are not the only facts that influence the greater or smaller precipitation of rain in various countries; we must also take temperature into account. All other things being equal, it rains more in a country the nearer it is to the equator, for the evaporation increases with the heat of the sun, and consequently the condensation of moisture produced by the conflict of the winds returns a greater quantity of water to the earth. Hotter than the temperate zones, the tropical zone is also watered by more abundant rains, in the same way that the temperate zones receive proportionately more moisture in the shape of rain and snow than the two polar zones.

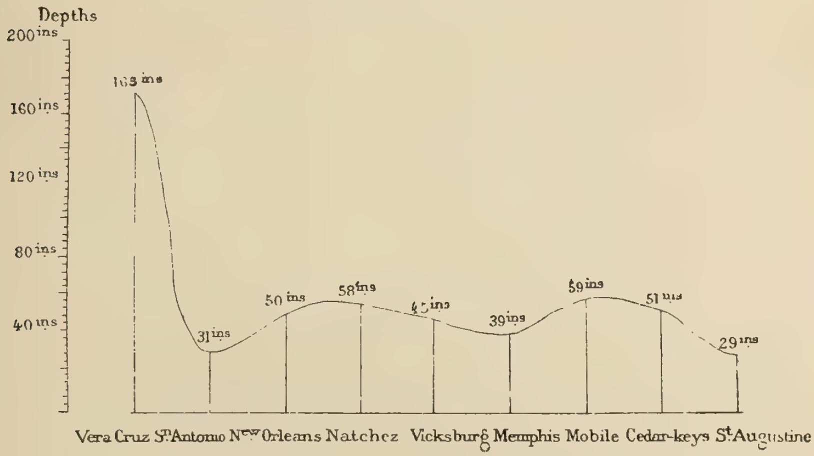
Between the tropics the rains follow with tolerable regularity the apparent course of the sun, and the season during which they fall to the ground is thus clearly defined. In fact, the trade-winds become charged with an enormous quantity of watery vapour in passing over the seas of the torrid zone; but their temperature augmenting in proportion as they approach the equator, they acquire a greater and greater capability of holding moisture, and preserve their relative dryness. Nevertheless, as soon as the regular winds from the south-east and north-east have arrived at their point of meeting in the equatorial zone, things suddenly change; the two aërial currents mount together into the high regions of the atmosphere, their temperature is lowered, the vapour with which they are saturated condenses, heavy strata of clouds are formed above the whole of the zone of calms, and are precipitated in floods of rain. The water falls, indeed, in such great abundance that sailors are often able to collect from the surface of the ocean the fresh water that they need. The English navigators have given to these parts of the sea the expressive name of *swamp*, as if the sea were changed into a sheet of brackish water; for Frenchmen the entire region has become the *Pot-au-Noir*, probably because of those sudden showers and irregular winds which succeed to the downfall of the rain. The zone of clouds which extends thus in a more or less continuous manner all over the ocean, is undoubtedly visible from the nearest heavenly bodies, and must resemble those whitish bands which our telescopes discover on the planet Jupiter.

The movement of the zone of clouds with the course of the sun over the ecliptic, causes the dry and rainy seasons to alternate regularly in the tropical regions. Thus the Antilles and the Republics of the American isthmus are successively

under the great girdle of rainy clouds and in the domain of dry winds. During the months of June, July, and August the sun, trailing beneath him the immense veil of vapours, is at the zenith of the countries near the tropic of Cancer; this is then the so-called winter-season or *hivernage;* vapours cover the heaven, and rain falls in abundance. As we may see by a comparison of the rain at Vera-Cruz and on the northern coasts of the Gulf of Mexico, the quantity of rain that falls exceeds by double or triple the average proportion of water received by the border countries situated beyond the zone of "hivernage." In September, when the girdle of clouds has again passed southward, the trade-winds resume their normal march in the direction of the equator. They absorb the moisture of the land and sea, and carry it further to the countries sheltered by the zone of clouds; then it is the dry season for the Antilles and Central America.

In Columbia the year is divided into four periods, two dry seasons and two wet seasons, produced likewise by the oscillation of the rainy zone. During the winter of the northern hemisphere the girdle of calms penetrates into the opposite hemisphere, and extends in breadth from the 2nd degree of north latitude to the 5th

Fig. 129.—Rains around the Gulf of Mexico.



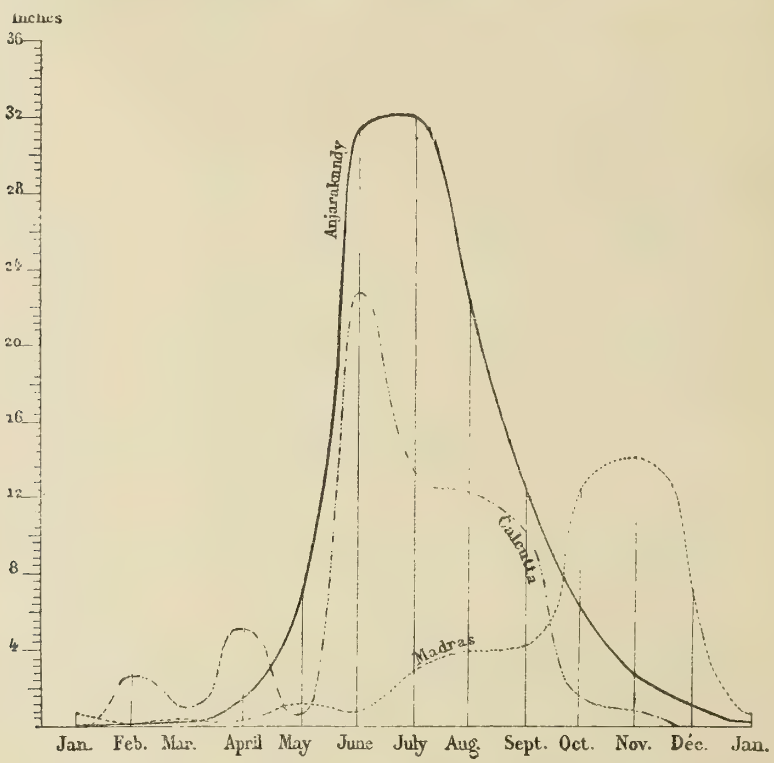
degree of south latitude. When New Granada is still under the influence of the trade-winds from the north-east the sky is pure and cloudless; this is the spring season, the *verano;* it rains only in the mountain valleys which cross the path of the winds. Towards the months of May and June, the girdle of calms is brought back to the north, and passes above the plateaux of Granada, inundating them with rain; this is the first hivernage, the *invierno.* But the cloudy masses continue their march towards the north, and stay only after having attained the 12th or even the 15th degree of north latitude. Then the Columbian plateaux are outside the zone of precipitation for the second time, and subjected to the influence of winds greedy for moisture, which bring with them a new dry season. Finally, towards the months of November and December the girdle of calms again crosses the latitude of Bogota, and the thirsty land instantly receives rain from the sky, till the wide band of clouds has disappeared in the direction of the equator.

To the south of the countries where the two annual passages of the cloudy zone cause the alternation of a double winter and a double summer, phenomena occur analogous to those of the Antilles and Guatemala. In the regions of the Upper

Amazons, as in Central America, there are only two seasons, the rainy and the dry, but these follow each other in inverse order: when it rains on one side the sky is azure on the other; when drought prevails to the south, the lands are inundated to the north. Besides, in both hemispheres the normal epoch and the abundance of the rains are variously modified by the form of the coasts, the relief of the plateaux and mountains of the interior, and the alternations of the monsoons. Thus the great rains fall in June and July at Calcutta, and at Anjarakandy on the coast of Malabar; at Madras the maximum is in November.

By a remarkable contrast, it is precisely at the time of the year when the heat ought to be greatest that the tropical countries are most refreshed by the precipitation of abundant rains. Extending like an immense veil, the clouds protect the

Fig. 130.—Amount of Monthly Rainfall at Anjarakandy, Calcutta, and Madras.



earth from the heat of the sun, which is then at its highest in the heavens. The winter-time, during which the temperature is often lower than in the warm season, is nevertheless the true summer from an astronomical point of view. We can judge of the influence which the tropical rains exercise on the temperature by the accompanying figure, the two lines on which represent, one the monthly amount of pluvial water at Anjarakandy, and the other the thermometrical variations. Thus the oscillation of the zone of clouds results in equalising the annual heat, and tempers the ardour of a summer which might be in the whole of the tropical zone what it is in the Sahara. It is true that often one feels more oppressed in the rainy season than in that of the great heat, because of the enervating moisture of the atmosphere.

Besides, we must not think that during the tropical rains moisture is precipitated constantly or even frequently at all hours of the day and night. On the contrary, in the greater part of the equatorial regions the rains obey a sort of rhythm. Ordinarily they only commence in the afternoon, because during the night and morning the atmosphere has not yet had time to be completely saturated with vapours; but when the air can no longer absorb any more moisture, the storm breaks violently in the midst of rapidly condensing clouds. On many points of the coast-line of the sea of the Antilles, in Columbia and Mexico, the sky begins to discharge its burden of rain towards two o'clock in the afternoon; but the

Fig. 131.—Amounts of Rainfall at Anjarakandy, with the Corresponding Temperatures.

shower is expected, and all preparations for shelter are made beforehand, and in the evening one may go out of doors again without fear. In the same way in certain parts of tropical Brazil, the hours of the daily storm are so well foreseen that rendezvous can be appointed at the end of the rain. However, there are tropical countries more abundantly watered where the showers of each day last till a late hour at night, or even into the morning. On the open sea, where the immense surface of evaporation can continually saturate the superincumbent atmosphere, the rains have a longer duration than on land, and they often continue for whole days.

CHAPTER XLII.

RAINS BEYOND THE TROPICS.—WINTER RAINS.—RAINS OF SPRING AND AUTUMN.—SUMMER RAINS.—RAINS OF THE POLAR REGIONS AND OF AFRICA.

TO the north and south of the zone of the trade-winds the rains, like the winds, present much less regularity than in the region of the equatorial calms, both in the quantity of rain that falls and in the time and duration of the rainy season. It is in the northern hemisphere especially that the precipitation of rain is accomplished in an unequal manner, for the surface is there more varied than anywhere else by the contours of continents, scattered islands, inland seas, and chains of mountains, which lie parallel, oblique, or transverse to the winds. Thus it is very difficult in many countries to discover the general order in which the rains succeed each other; and so long as conscientious observations have not been made during any series of years, uncertainty must prevail in this respect.

However, the registers kept at the various meteorological stations of the northern hemisphere are already sufficient to show what is the normal distribution of the rains on this side of the tropic of Cancer. To the north of the variable limit where the trade-winds commence, and as high as a latitude of forty degrees, the rains fall almost exclusively during the winter. Around the basin of the Tyrrhenian sea, and on the coasts of Western Europe, they are distributed throughout the year, but it is especially in autumn that the greatest precipitation of moisture takes place; more to the north it is the summer which is the especial rainy season; finally, in polar countries it is in the winter that the condensation of the clouds produces the most rain and snow.

The direction of the winds is the true cause of this unequal distribution of the rainfall according to the various parts of the year, for beyond the equatorial zone most of the showers are, so to speak, not formed on the spot by the condensation of the ascending vapours, but are brought from afar by the currents of the atmosphere. During the winter of the northern hemisphere the whole system of trade-winds is attracted to the south following the sun, and consequently the aërial counter-currents which return towards the Arctic pole can descend again to the surface of the globe in the neighbourhood of the tropic of Cancer. The vapours with which these winds are charged are then condensed into rain in consequence of the mingling of the air which carries them with other and colder atmospheric masses; this is the rainy season. But when the sun approaches the equator, bringing with it towards the north the entire system of winds, the counter trade-winds of the south-west cannot then approach the surface except towards the middle of the temperate zone.

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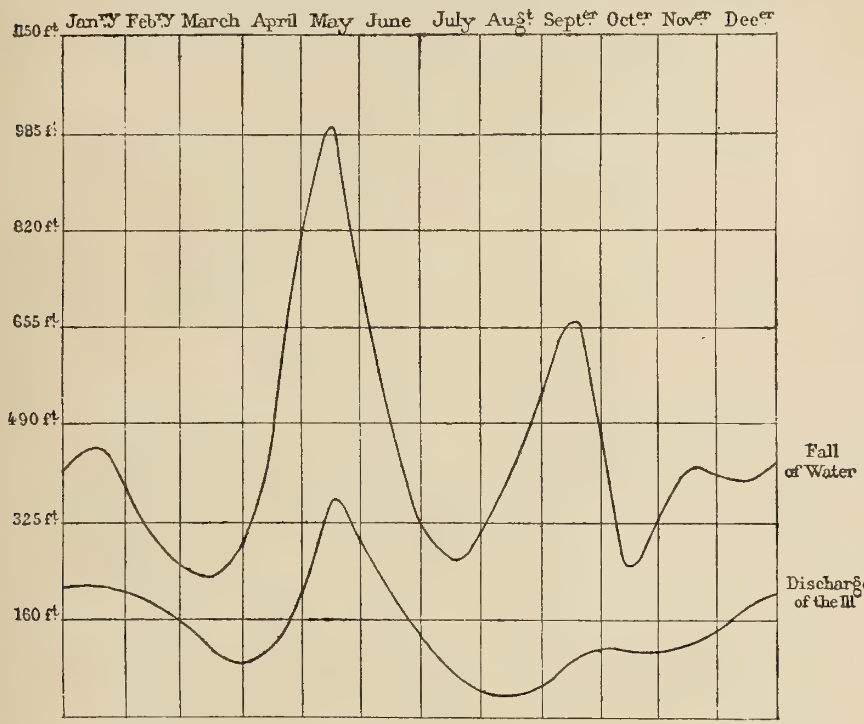
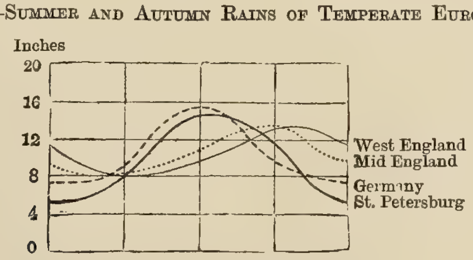
The sky becomes bright again in the regions which had been inundated with rain; a relatively dry period commences in the spring, and lasts until the sun has again crossed the equator towards the southern lands. This alternation of the seasons is accomplished with great regularity on the coasts of California and Oregon, at

Fig. 132.—Amount of Rainfall in the Basin of the Ill, and Mean Discharge of the River, during the Year 1856.



Madeira, in Algeria, and on the coasts of Portugal. It is thus that at Lisbon only 0·16 inch of rain falls in July, whilst in December the total precipitation is 4·9 inches. At Naples and even at Rome summer droughts, rarely disturbed by showers, follow the winter rains.

Fig. 133.—Summer and Autumn Rains of Temperate Europe.

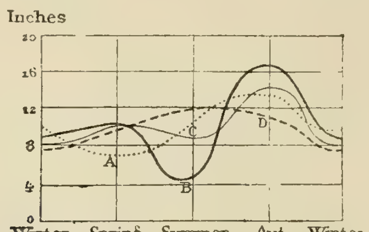


As to the region of the spring and autumn rains, it ought to comprise the countries over which the returning trade-winds blow at the epoch when the sun is at the zenith of the equator; this is the equinoctial period of March or September. In certain countries in the south of Europe, and especially in Provence, we observe,

in fact, that the rains are most abundant in spring and autumn. Even in Alsace the greatest quantity of rain falls in spring, and flows into the tributaries of the Rhine, as is shown by Figures 133, 134, which are borrowed from a work of M. Charles Grad; but with some exceptions the maximum of autumn is generally the highest of the two, and that of the spring ends by disappearing entirely in a northerly direction. The western coasts of France and the British Islands are comprised within this zone where the autumnal rains regularly predominate. The true cause of this excess of precipitation during the autumn season, compared with spring, has not yet been proved; it must doubtless be sought in the fact that, under the influence of the various atmospheric and marine currents, the fall of the temperature after the heat of summer is accomplished in a relatively abrupt manner. The descent of the thermometer in autumn is more rapid than its ascent in spring. This is the result we obtain from most of the meteorological tables kept in the countries of Europe and North America.

More to the north, in the temperate zone, it is no longer in autumn but in summer that the rains water the earth with the greatest abundance. In the whole of central Europe, from the Vosges to the Ural mountains and beyond, to the shores

Fig. 134.—Autumn Rains of France.



A. West France. B. Rhone Basin south of Viviers.
C. Rhone Basin north of Viviers. D. East France.

of the Sea of Okhotsk, the greatest precipitation of moisture takes place in the warmest part of the year. This is because the sun, being then above the tropic of Cancer, has brought back to the north the entire system of the trade-winds and counter trade-winds; these latter, therefore, descend to the surface of the earth in high latitudes only, and there alone, in consequence of their conflict with the cold winds of the polar regions, is produced this notable increase of rain, owing to vapours brought from the tropics.

On the other side of the equator it is in exactly the opposite way that the counter trade-winds of the north-west, travelling with the sun, determine the greatest precipitation of moisture over the countries towards which they sink. As to the snows of the two polar zones, they fall most of all in winter, that is to say, during the long night which lasts several months, for the temperature of the atmosphere is then too low to retain in suspension the moisture brought by the equatorial winds.

The remarkably regular distribution of rain over the African continent has been carefully studied and described by Keith Johnston, who well observes that as there is no other region stretching out so equally on both sides of the equator, so there is no other portion of the globe which illustrates on such a large scale the pluvial phenomena here described. " Eastward, the trade-winds of the Indian Ocean blow towards Africa; westward, those of the Atlantic draw away from it; the land intervening, with its more rapid changes of temperature, to break, in some

degree, the continuity of those great streams. Barometric observations show very distinctly that an area of low pressure, or an ascending column of air, is always formed over that portion of Africa which happens to be beneath the vertical sun; and, as the source of heat apparently moves back and forward between the northern and southern tropics, this ascending column follows its march, drawing to itself streams of air from the surrounding regions.

"Southern tropical Africa is surrounded east, west, and south by the ocean, so that when the vertical sun and its accompanying indraught are moving over this part of the continent, the inflowing winds bring with them the vapours from the sea to condense and fall on the heights of the land in copious showers of rain; the south-east trade-wind of the Indian Ocean keeping up a constant supply of vapour-laden air, and being the great provider of the rains of South, Central, and Eastern Africa. From the broad Gulf of Guinea come the supplies for the western equatorial region and the greater part of the Sudan. If the whole continent were similarly girt about by the sea, the same system would without doubt extend to Northern Africa also: copious showers would water every part of the northern tropical region when the sun was vertical over it, and the Sahara would no longer remain arid and dry.

"To north and east of Africa, however, stretches the great continent of Europe and Asia, separated only by the comparatively small and narrow Mediterranean and Red Seas. The presence of this land interferes to alter materially the whole system of movements of the atmosphere over North Africa, and to render large areas of it barren from deficiency of moisture. The same indraught follows the vertical sun thither in its passage towards the northern tropic, but the moist winds drawn northward after it from the Indian Ocean, and especially from the Gulf of Guinea, expend their stores of rain over the broad belt of the Sudan, and are exhausted on reaching the southern borders of the Sahara. No rain can come from north or north-east, for the winds from these directions are robbed of their vapour in passing overland, and in the west, between Marocco and Senegal, the steady north-east trade-wind of the Atlantic blows persistently away from the African shores.

"The presence of the Asiatic continent also disturbs the regular flow of the trade-wind current over the whole of the northern Indian Ocean and its surrounding lands, altering and controlling the march of the winds, and with that, the rainfall of all this region. During the northern declination of the sun, from April to September, as in Africa, so in central and southern Asia, at the hottest season of the year a strong indraught of air from all sides flows to the heated land; and then the great current, known as the south-west monsoon, blows steadily towards India from the east African shores across the Arabian Sea. At this season the south-east trade-wind coming up past Madagascar appears to feed the monsoon current, joining with it as a southerly wind on the east African coast opposite Zanzibar, and curving to north-eastward with it in one continuous stream towards India. It brings up the vapours from the south Indian Ocean, and carries these northward to form the heavier rains of the Zanzibar coast and of the Somâli promontory and Abyssinia.

"During the southern declination of the sun, on the contrary, when the central Asiatic continent has just as excessive a winter cold as it had summer heat, the cold heavy atmosphere descending over it flows outward from the land on all sides, and then a dry north-easterly wind stream, warming as it advances towards the equator, takes the place of the former south-westerly monsoon across the Arabian

Sea; and blowing in towards the hot lands of South Africa, brings the drier season to the north-eastern coast-lands between Somâliland and Zanzibar.

"The rains of inter-tropical Africa are thus controlled for the most part by the indraught which pendulates with the vertical sun on the continent itself, and by the monsoon winds of the north Indian Ocean, which are in part governed by the heating and cooling of Asia. The continent, however, stretches beyond the limits of the tropics north and south, passing outside the zone of the trade-winds and entering the belts in which westerly winds, blowing not towards, but generally away from, the tropical zone, prevail throughout the year. The parts of Africa which extend into these belts of westerly winds are those which lie beyond the 30th parallel of latitude in each hemisphere—the Cape Colony in the southern, and Marocco, Algeria, Tripoli in the northern. In contrast to the inter-tropical region, in which the hottest season corrresponds to that of greatest rainfall, these extremities of the continent have their chief supplies of rain in their winter season, or when the vertical sun is farthest from them. The rains begin first to fall when the temperature of the land has sunk to such a degree as to condense over it the vapour brought by the westerly winds from warmer latitudes. Thus the westerly winds from the South Atlantic condense in a bountiful supply of winter rains over all the south-western region of the Cape Colony, from April onward to September, when the vertical sun is *north* of the equator. In Marocco and Algeria, correspondingly, the west winds of the North Atlantic provide the winter rains of these high lands, when their temperature is lowest, or when the sun is *south* of the equator, from September onward to March or April; and it is remarkable that the least favoured portions of the Maroccan and Algerian coast-lands are those opposite the narrowest part of the Mediterranean, between which and the Atlantic the broadest extent of the Spanish peninsula intervenes. Farther east, on the coasts of Tripoli and Egypt, the scanty winter rains seem to be supplied from the vapours of the Mediterranean itself.

"Two other portions of the continent, remarkable in their physical character, notice deserve from the exceptional nature of their rain supply. These are the high wedge-like tableland of Abyssinia, and the steep northern face of the Somâli promontory, where it descends abruptly to the Gulf of Aden. In both of these regions, though they are within the tropics, a rainfall occurs in what may be termed their winter months, when the sun is nearest the southern tropic. At this season, as we have seen previously, the north-east wind from Asia is blowing across the Arabian Sea towards southern Africa, then heated by the vertical sun. Down the Nile valley also at this period cool north winds are flowing towards the warm south. Obstructing the advance of these winds, the high lands of Abyssinia and northern Somâliland condense upon themselves the vapours gathered from the Red Sea and the Gulf of Aden. Thus the Abyssinian plateau has its earlier rains in the cool months of January and February, when all the low land of Africa to east and westward of it is perfectly dry; and the high south coast-land of the Gulf of Aden has its rains from December to March and April, when the interior of Somâliland is so parched as to have become '*Abar*'—a place of famine."—*Africa*, pp. 569-72.

CHAPTER XLIII.

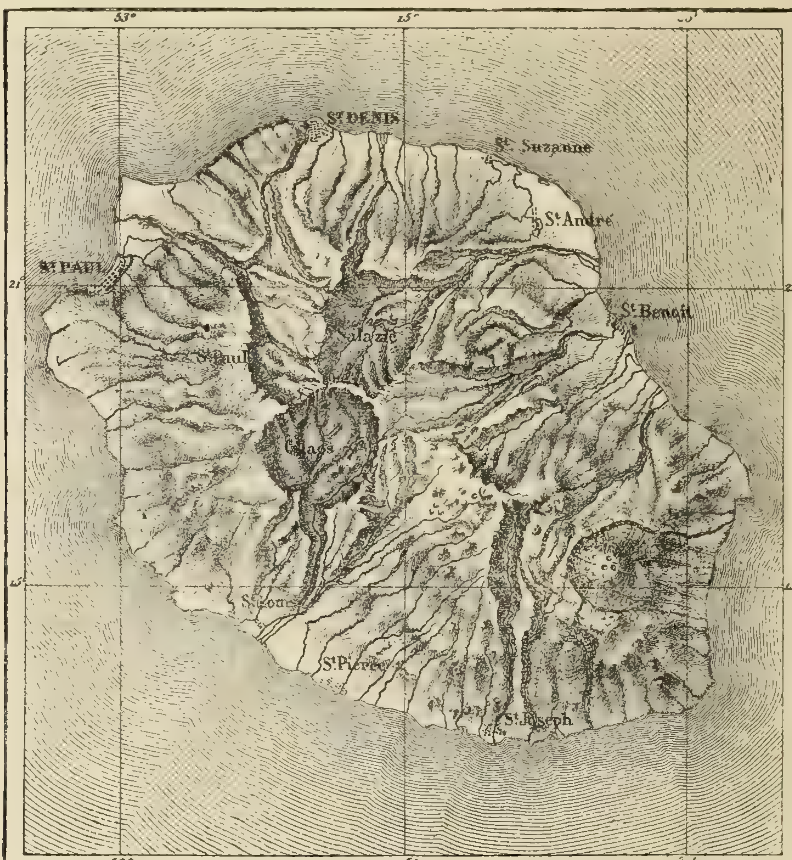
COUNTRIES WITHOUT RAIN.—GEOLOGICAL ACTION OF RAINS.—CONTRAST OF THE TWO HEMISPHERES.

THUS in all parts of the earth, from the equator to the poles, the rain is distributed with a certain regularity according to the seasons. In many regions it falls exclusively during a fixed period of the year, in other countries the alternation is not divided so clearly between the rainy and the dry season. It often rains during the winter months as well as during the summer months. But a regular oscillation is observed between the two periods of the greatest and least precipitation. Still there are certain countries where rain is almost entirely wanting, and these countries are found for the most part situated precisely in the neighbourhood of the equator and the tropics, where the waters, heated by the sun, furnish the greatest quantity of vapour to the atmosphere. In regions like the coast-line of Peru, which stretch at the foot of high mountain-ridges rising on the path of the rainy winds, the constant dryness of the atmosphere must be solely attributed to the form of the surface of our planet. It is sometimes sufficient to cross a single pass to ascertain the enormous difference which exists in a meteorological point of view between the two slopes. On one side the winds, laden with moisture, frequently let fall their burden of rain; on the other side the aërial currents, lightened of their vapours and heated by the reverberation from the white rocks and bare earth, greedily absorb, on the contrary, the little water which flows in the valleys. The trade-winds from the north-east and south-east, which discharge on the eastern slopes of the Cordilleras such an abundance of rain as to form the Japura, the Putumayo, the upper Maranon, the Apurimac, the Mamoré, and so many other mighty tributaries of the magnificent current of the Amazon, do not let a single drop fall on the western slope, which is transformed almost into a desert, and traverse the surface of the Pacific to a great distance into the open sea before having collected enough vapour to discharge fresh rains. On the coasts of Peru the air is often misty, but through this whitish veil the blue sky can be always distinguished; the appearance of a cloud is a real event, and the whole population assembles to contemplate this unaccustomed spectacle. On the western shores of Mexico, where the winds are much less regular than in South America, the atmospheric disturbances occasion the fall of violent showers at times; but, as in Peru, the great mass of rain-water is retained by the plateaux and mountains which rise to the east, across the path of the trade-winds and monsoons. More to the north the meteorological phenomena occur in an inverted order. The rainy

winds which strike the summits of the Coast Range and Sierra Nevada are the counter trade-winds of the south-east; they abundantly water the slope which faces the Pacific. But beyond the Rocky Mountains they are entirely dried-up, and the deserts of Texas, New Mexico, and Colorado would be absolutely without water if the monsoons from the south did not bring a little moisture. The mean quantity of rain which falls in the solitudes to the west of the Mississippi is estimated at two inches only.

But in the neighbourhood of the tropics, and even some way into the temperate zone, there are other regions freely traversed by winds laden with vapours, which

Fig. 135.—Ravines in the Craters of Reunion



are nevertheless very rarely watered by rains. A wide tract of land almost without water stretches diagonally across the Old World, from the western plains of Africa to the plateau of Eastern China. This zone disposed in an immense arc, the concavity of which is turned towards the north-west, comprehends a great part of the Sahara, the deserts of Egypt and Arabia, the high lands of Iran, various tracts of Turkestan and China, and the plateau of Gobi. In the southern hemisphere the three continents, Africa, Australia, and South America, have also each their zone of dry lands situated in the neighbourhood of the tropic of Capricorn. In Africa it is the desert of Kalahari; in Australia it is the fearful solitudes which explorers have to traverse on their way from the southern colonies to the Gulf of

Carpentaria; in South America it is the Pampas. If these several countries to the north and south of the equator are thus destitute of rain-water, the cause is principally the trade-winds, which, in their regular passage across the continents, constantly absorb fresh quantities of vapour in proportion as they approach the zone of the equatorial calms; and their temperature also increases. Nevertheless, it would be very difficult to trace the exact boundary of the regions destitute of rain with those where the precipitation takes place regularly, for all round the countries of prolonged drought the monsoons form a sort of irregular border, changing year by year. Besides, the plateaux and groups of mountains placed in the midst of desert regions, the Jebel-Hoggar in the Sahara, the Demavend to the north of Persia, the huge pile of Cordova in the Argentine Pampas, raise their summits high into the air, and force the chilled winds to yield to them a part of the vapours that are carried towards the equatorial zone. As to the plateau of Gobi, situated in great part beyond the zone of the trade-winds, the dryness of its climate is caused by the mountains which surround it, and by its distance from the sea.

As is shown by the aspect of all deserts, rain is the great geological agent on the surface of the earth. The immense indentations made in the edges of plateaux and the flanks of mountains, are due for the most part to the action of rains and streams which wear away the clays, carry the sands along with them, lay bare the rocks and drive them before them, and also assist in the destruction of the shores. In all the rainy countries whose surface is greatly varied, it is absolutely impossible to recognize what was the primitive aspect of the land, so much has been done by the rains in sculpturing anew the fissures and inequalities produced at first by other agents. Thus, in most of the volcanic countries, and especially in the Island of Réunion, the ancient craters have been hollowed out and worn by the rain, and finally transformed into circles similar to circles of erosion. According to Lyell, the Val del Bove, which opens on the eastern slope of Etna, is also an ancient volcanic crater, whose walls have been partially destroyed by the rains.

Where rain is wanting the surface presents a singular monotony over vast tracts. It is undoubtedly to the absence of the rain and the dryness of the atmosphere, that the Argentine Andes owe the peculiar uniformity of their relief; there we see none of those long valleys, those deep ravines and wide crumbling cirques, which give such a picturesque character to the architecture of the Pyrenees and the Alps. Since the epoch when the waters of the sea retired, carrying to the foot of these mountains of the New World the enormous heaps of rolled pebbles which we see there now, the snows and rains have not yet fallen in sufficient abundance to hollow out the declivities and cut them into valleys and counter-forts. Seen from below, the rampart of mountains presents the aspect of a uniform and blackish wall, above which rise here and there a few peaks striped with white lines. The plateau, from 13,000 to 14,000 feet in average height, upon which these isolated mountains rise, is in many places almost perfectly level over a breadth of 50 miles. A few low hills scarcely break from time to time the monotony of the great plain; in the deepest depressions are seen small lagunes of water, almost always very saline. The vegetation is absolutely nothing, not because of the intensity of the cold, but because of the dryness of the air and the violence of the wind which blows in these high regions; one single plant grows at the height of 13,000 feet, the *Llareta*, a kind of lichen with a strong root, which spreads over the rocks like a green mould. The snow, which rarely falls on these heights, melts or evaporates when it has barely escaped from the clouds. In the middle of the day these snow vapours rise in thin clouds, which are lost at great heights in the blue atmosphere; one would say they

were fireworks ascending into the sky. The air of these regions is sometimes so dry, that the skin of travellers cracks and their nails break like glass.

The exact proportion of rain which falls in the various countries of the earth, so indispensable to our knowledge of meteorological laws, is thus found to be also of the greatest importance, from a geological point of view, since it enables us to explain the form of the mountains, the general aspect of countries, and the state of the vegetation which covers them. This is not all: the distribution of rain is likewise an astronomical phenomenon. For by the comparison of the amounts of rainfall observed over the surface of the globe, one can learn exactly the contrast which is presented between the two hemispheres in respect of the precipitation of moisture. And this contrast, whatever its importance may be, is intimately connected with the unequal distribution of heat in the two halves of the planet, and, in consequence, of the form of the orbit which the earth describes round the sun.

It results from a comparison of observations that the greatest proportion of rain-water falls in the northern hemisphere. According to Keith Johnston, who unfortunately was able to quote but a somewhat limited number of meteorological facts, the amount of rain which falls on an average during the year on the surface of the earth to the south of the equator is 26 inches; to the north it is about 37½ inches; that is to say, about half as much again.

These figures seem a little too high, and will undoubtedly be sensibly modified by future researches, which embrace a greater number of stations and a longer period of years. But it is very probable that the difference noticed between the two hemispheres in respect of the precipitation of rain-water will always remain considerable. In fact, it is in the northern hemisphere that we find the zone of equatorial calms where the rains fall in the greatest abundance during almost all the year. It is in the northern hemisphere, too, that the monsoons, attracted by the heated continents, discharge those prodigious showers, and supply the earth in a few weeks with more water than falls from the clouds in other climates in several years. Almost all the great rivers, also, with the exception of those which flow into the estuary of La Plata and the tributaries of the right bank of the Amazons, have their source in the northern hemisphere. The continental surface which is found to the north of the equator is three times the extent of that which stretches to the south, while the amount of rain, estimated roughly according to the yet incomplete data which we possess, is at least five or six times as great.

Now, by a remarkable contrast, the northern hemisphere, which receives the greatest quantity of water, supplies the least proportion of it. In fact, the ocean, restricted to the north by continents, spreads on the south of the equator so as to cover almost the entire circumference of the earth. It thus presents to the solar rays an immense surface of evaporation, incessantly feeding the clouds of the atmosphere. In this way that half of the globe which furnishes the most vapours is that which receives the least rain in exchange; a circuit of the aërial currents is therefore necessarily established between the two hemispheres, and thus equilibrium is maintained. It is in great part the vapours from the Southern Atlantic, and perhaps also from the South Sea, that supply the rivers of Europe.

CHAPTER XLIV.

HEIGHT OF THUNDER-CLOUDS.—DISTRIBUTION OF THUNDER-STORMS IN VARIOUS REGIONS OF THE EARTH.—COURSE OF THESE PHENOMENA.

THE condensation and the precipitation of watery vapour are always accompanied by electrical phenomena; but this powerful force, which acts incessantly on the surface of the globe, does not manifest itself in a visible manner in ordinary rains, for by them the atmospheric equilibrium is hardly disturbed. But when the clouds are suddenly condensed, and when the ground and the various strata of air are very different in temperature and electrical tension, harmony can only be re-established by violent discharges, accompanied by lightning. It is then that we see in the sky, which is black with clouds, the magnificent spectacle of those dazzling flashes which spread in sheets or shoot in long zigzag darts. One instant the terrible light fills the sky, then space is covered anew with darkness, and we hear bursting from the gloom the immense voice of the thunder which reverberates in dull echoes from the clouds and the ground. In violent thunder-storms the detonations sometimes follow each other so closely that the horizon is lit up all round with one continuous flash, while crashes and long rollings of thunder echo from various points of the sky at the same time, and rain falls in torrents from the rent and broken clouds. Often, too, these storms shower upon the ground a mass of hailstones formed of concentric layers of frozen water surrounding a small crystal, sometimes very regular in form. Every one of these storms, however, differs in its proceedings. Some are simply passing phenomena, others are electric whirlwinds, or they may even be considered as real cyclones. In these terrible tempests lightnings six and even nine miles long have sometimes been seen.

The principal zone of thunder-clouds extends at a considerable elevation above the ground, as is easily ascertained on heights. "Mountains attract the thunder," say the proverbs of almost all nations; and it is in fact on the great elevations of the terrestrial surface, where the clouds strike and are condensed into water, that the electrical discharges most frequently take place. Besides, isolated and pointed rocks must act as so many natural lightning-conductors, and they are consequently much oftener struck by lightning than the lower walls of the mountain-gorges. It is to the repeated action of these phenomena that we must attribute the singular magnetic state of those rocks, near which the mariner's compass is disturbed, and takes, without any apparent rule, the most varied directions. Forbes and Tyndall cite a remarkable example of this phenomenon on the Rieffel Horn of Monte Rosa, at more than 9000 feet high. Humboldt has seen rocks split by the lightning at the summit of the mountain of Toluca in Mexico, at 15,000 feet above the level of the

sea. Messrs. Peytier and Hossard have observed some Pyrenean storms which were formed at still greater heights. In a general way we may say that the height of these electrical storms is that of the great "cumuli," from which they take their origin.

Thunder-storms, like simple rains, burst more frequently in the elevated gorges of mountains turned towards the sea than anywhere else. It was because of the numerous tempests which assailed the rough coasts of Epirus and Illyria, that the Greeks made the Acroceraunian mountains the seat of Jupiter, "the hurler of thunder;" still these mountains are little visited by storms in comparison with several chains which rise in the tropical zone on the shores of the ocean, and transversely to the direction of the rainy winds. Thus the Sierra Nevada of Sta. Marta in Columbia has a storm every day, and the few travellers who climb one of these great peaks above the zone of tempests may expect, from two o'clock to four o'clock, to see the magnificent spectacle of a tumultuous sea of clouds, all trembling with lightning, unroll beneath their feet.

In general, thunder-storms are most numerous in a country where rains are most abundant. The zone of equatorial calms and that of the monsoons, where moisture

Fig. 136.—Average Number of Storms in Europe.

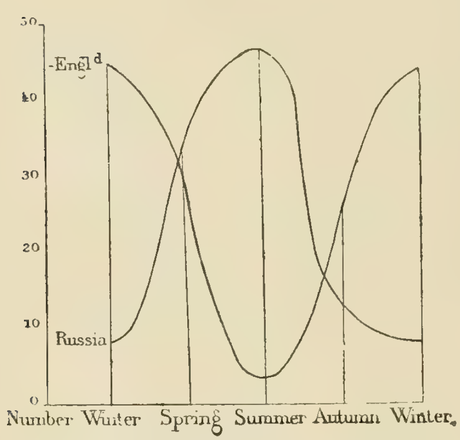
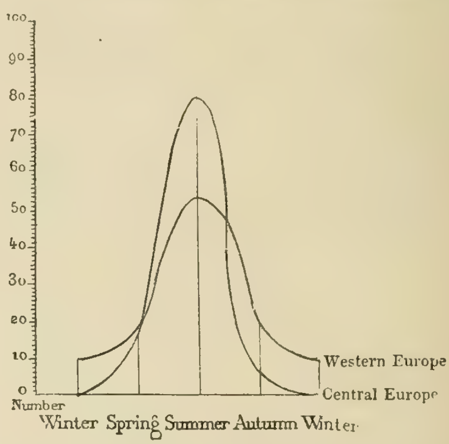


Fig. 137.—Proportion of Hailstorms during the Seasons in Russia and England.



is precipitated in such considerable quantities, are also the regions of the earth where it thunders most frequently. In Bengal the annual number of thunder-storms is from 50 to 60; in the Antilles about 40 are counted per year; under temperate climates there are only about 20, and these occur almost always during the warm season. In Eastern Europe it is almost unexampled, so to speak, that they break out in winter. But on the western coasts of the continent, which are subject to the tropical influence of the Gulf-stream, these stormy conflicts of the air take place also in the cold season. It is a curious fact that it is in winter that the greatest quantity of hail falls in Great Britain. In the direction of the poles the number of storms gradually diminishes. In the north of Europe thunder is a very rare phenomenon, and it is even said that in Iceland and on the coasts of Spitzbergen—that is to say, precisely in those countries where the magnetic aurora shines—lightning has never been seen in the sky. The countries of the tropical zone, which do not receive any rain, like the coast-line of Peru and Bolivia, are also exempt from thunder-storms. The lightnings which are sometimes seen by mariners sailing towards the open sea from the coasts are merely reflections of those

that escape from the clouds at hundreds of miles to the east, on the eastern slopes of the Cordilleras.

As the number of tempests diminishes gradually from the equator to the poles, so are they reduced little by little in the open sea in proportion to their distance from the shores. This is a pretty general rule, at least in the seas of the torrid zone and the Antarctic Ocean. According to Arago and Duperrey, who have collected all the observations made before them on the tempests of the sea, no sailor has ever heard thunder in the middle of the South Atlantic, nor in the great ocean of the south between Easter Island and the islands of the antipodes. It is because

Fig. 138.—Storms on the 9th of May, 1865.

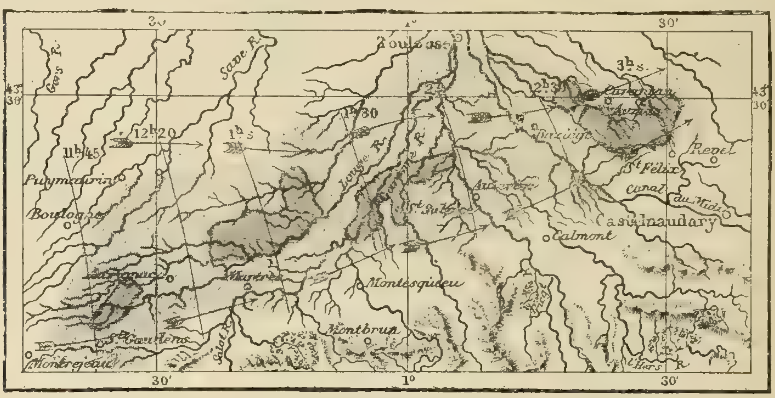
of the relatively small number of storms breaking out on the open sea that ships, which attract lightning by the form of their masts, have been able to escape being struck.

Taken as a whole, the thunder-storms of Western Europe follow the same general direction as the tempests, and often accompany them on their course. This is shown most clearly by the meteorological maps of France, drawn up since 1865 at the Observatory of Paris. The storms are not there purely local phenomena, as was even recently supposed, but on the contrary, they form part of the general system of atmospheric changes. It is proved by thousands of observations made systematically in different parts of the French territory, that almost all the thunder-storms come from the ocean; very often the inhabitants of the coasts hear

the rumbling of the thunder several hours before the storm breaks over the continent. In the same way in Germany, and even in Russia, thunder-clouds from the enormous basin of evaporation of the Atlantic come from the west and south-west. Nevertheless there can scarcely be any doubt that the storms of the Mediterranean basin, which burst on the southern slopes of the Cevennes, the Maritime and Lombard Alps, have their origin in the atmosphere overhanging the great inland sea itself. From the summit of the Aigonal they may be observed rolling up from the Mediterranean, and expending their force on the lower escarpments of the southern highlands.

It is, therefore, in quite an exceptional manner that rapid ascending currents, charged with moisture from the lakes and rivers, produce storms in the very interior of the continents. But on the various points of their path thunder-storms from the ocean are generally much modified by the medium through which they are propagated. Above regions differing from one another by the irregularities of the ground, nature of the soil, vegetation, and climate, the thunder-storms pass by abrupt passages, from relative calm to fury; here the thunder rolls incessantly, and hail beats down the crops; there the clouds only discharge rain: still further,

Fig. 139.—Storm in the Plain to the North of the Pyrenees.



the wind drives the torn clouds before it without a single drop of rain falling. It is because of these great inequalities in the advance of the tempests that it is often difficult to recognize a regular series in the disturbances which succeed each other over distant parts of the same country.

The secondary storms which are formed here and there on the track of the principal atmospheric current are the more influenced in their march by the accidents of the ground and the variations of temperature, the less considerable they are, and the nearer they approach to the terrestrial surface. They also present the greatest variety of speed, and deviate frequently from their normal direction to spread along mountains, hills, or forests. Thus, as M. Becquerel has proved in his meteorological studies on the centre of France, the greater part of the secondary storms regularly follow the course of the great valleys, like so many aërial rivers superimposed on the liquid rivers which roll below. When a thunder-storm, after having originated on a lateral plateau, directs itself obliquely towards a valley, it changes its course above the river, and never fails to follow its meanderings either up or down, as if it formed a bed for its own course in the great fosse of the valley. The storms which proceed at right angles to the direction of the river

are the only ones which turn neither to the right nor to the left to enter the great depression which is open to them, the force which tends to carry them along parallel to the valley not being powerful enough to cause them to deviate from their route.

If the storms are attracted, so to speak, by the roads which the larger valleys present to them, it seems equally proved that they seek to avoid the forests. Thus the various currents of clouds charged with hail, which ravage more or less periodically the plains of the Loiret, pass round the forest of Orleans, or, at least, damage only its very edge. Whence arises this relative immunity of trees? Do they retard the current of air by their crowded trunks, and thus force it to let fall its burden of hail outside, and then to flow laterally, respecting the thick mass of

Fig. 140.—Hailstorms of Orleans.

The grey tint indicates the region affected by the storms.

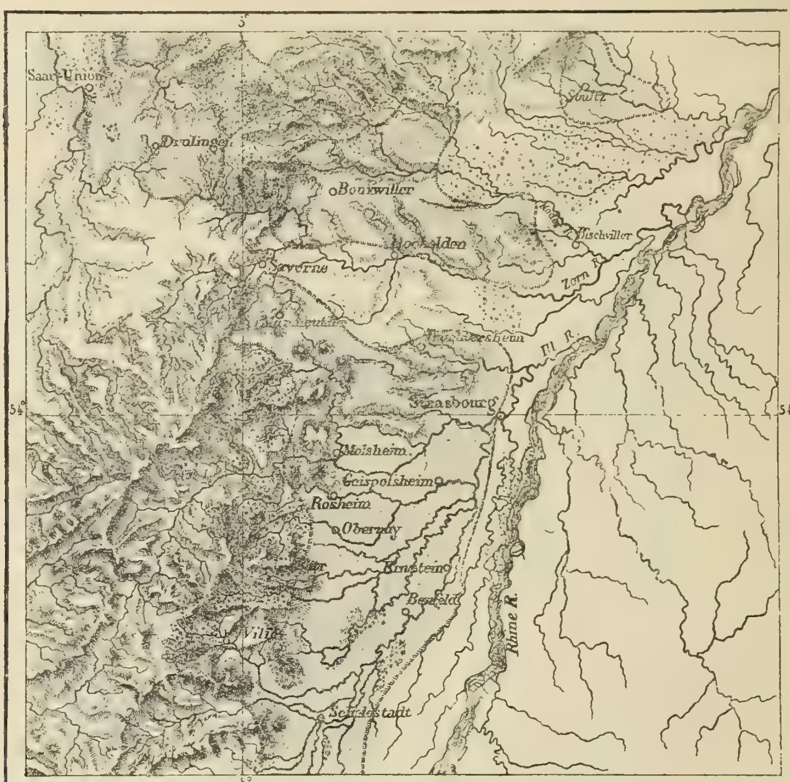
the forest? Or do they act as lightning-conductors on the clouds, thus preventing the hail from being formed? These questions are still much discussed; but however it may be, it is certain that the forests often cause the hail devitoate, and that the uprooting of trees often results in the modification of the regular course of the storm at the expense of agriculture. The numerous meteorological maps drawn up by M. Becquerel and other learned men, do not allow of a doubt that the zones in which hailstones most frequently occur are really modified in their extent by the distribution of forests over the territory.

At Casalbona, in the province of Naples, hail was known only by name so long

as the uplands situated in the north-west remained covered with forests; but since those forests have been cleared and the ground brought under cultivation, scarcely a year passes without the occurrence of hailstorms.

Not only the form and direction of the valleys, as well as the greater or less extent of the forests, give to the ground the power of calling up or allaying storms, but it seems, also, that the geological composition of the rocks exerts an influence of the same nature. Thus, to cite only two examples, certain masses of diorite in the Department of Mayenne dissipate or turn aside all the storms; while above the iron mine of Grondone, in the Apennines, a cloud forms almost every day during the months of July and August, and regularly bursts in claps of thunder towards four or five o'clock in the afternoon. Nevertheless, these are phenomena for which

Fig. 111.—Hailstorms of the Lower Rhine.



The part tinted indicates the regions of hailstorms.

no certainty is as yet obtained. According to M. Fournet, the savant who has best studied the laws of the rains and winds in the basin of the Rhone, the nature of the rocks and vegetable soil, the extent of cultivated fields, pasturage, and forests, exercise but a slight influence on the distribution of storms; the direction and depth of the valleys, the height and precipitancy of the salient points of the earth, are much more important in this respect.

This question of meteorology is still very obscure, as are those relative to the fall of hail. Why under temperate climates is the zone of hail, which forms above the plains, almost always narrower than that of the storm itself? Why is the fall of hailstones such a rare phenomenon under the tropics, at least in the regions of

the plains? Why during a whole century has it only hailed once at Havannah? Science is not yet in a position to answer with certainty. In regard to the formation of hail, the theories are contradictory to each other; and it is asked how hailstones, those heavy projectiles, weighing as much as 7 ounces to 10 ounces, can be crystallized in the heights of the air, and most frequently in summer, a little after the hottest hours of the day. What is the most probable, is that those whirlwinds which always occur when two opposite currents meet are the great producers of hail. In consequence of the centrifugal force the air is rarefied in the centre of the whirlwind, drops of water are congealed, and whirl in the great eddy, while at the same time cold air from the upper frozen regions is sucked down the immense funnel which is formed in the midst of the clouds, and thus the hailstones revolving in the vapours incessantly increase in bulk and number till they are dashed to the ground by the whirl of the grey clouds surrounding them. This theory, which is that of Mohr, Lucas, and Hann, explains why hail is so rare in tropical regions, where the strata of frozen air are too high for the whirlwinds of clouds to be able to draw them down in their eddies. The appearance of the stormy nimbus, the small extent ravaged by hailstorms, the oblique fall of the projectiles, together with the violence with which they strike the earth, and the gyratory direction taken by the corn thus beaten, are facts which give a great degree of plausibility to this hypothesis of the German savants.

Nevertheless, it seems useless to seek any other causes for the formation of hailstones than the natural congelation of the molecules of water in the chilled atmosphere, the transportation of these crystals by the wind, whose sudden gusts always assume somewhat the form of whirlwinds, and the agglomeration in frozen masses during their descent. The moisture precipitated in the form of hail on the slopes of the Alps falls as rain in the lower valleys. Thus, according to the varying temperature of the contending currents, the storm gives rise in one place to watery drops, in another to crystals. The spray of cascades falling from a great height is often transformed to hail in winter, as was noticed by Ramond at the foot of the Staubbach Falls.

A simple icy film is first produced; but this film, transported laterally by a rapid wind, meets other drops which have also been changed to crystals or needles. The molecules wafted on the breeze become gradually agglomerated at first in light masses according to the direction of the clouds; then they fall towards the ground, describing a parabola whose curve is determined by their own weight, and by the force of the wind driving them forward. An incessant rumbling is heard, produced by the wind, which is expending its strength on bodies to which it is unable to communicate a velocity equal to its own.

A more or less active state of electricity may also influence the crystallizations which are produced on the surface of the hailstones, thus giving rise to that phosphorescence which has so often been observed in hailstorms. But, says Brito Capello, the laws of this phenomenon seem to differ from those of thunder. At least, it seldom happens that storms accompanied both by thunder and hail occur in the same district. In any case the force of the aërial currents contending with each other during the formation of hail must be of a most formidable character, for hailstorms are sometimes heavy enough to produce what may be described as temporary glaciers. On May 9, 1865, the mass of crystals which fell in the district of Catelet formed a bed over a mile long and 650 yards broad, with a total volume estimated at 21,000,000 cubic feet. Four days afterwards the hailstones had not yet entirely disappeared.

Many facts relative to the cause of storms are still unknown: no reason can be given for the fact that on the shores of the North Sea, of the Gulf of Bengal, and many other regions bordering on the ocean, thunder-storms almost always commence at the hour of high tide. Another very strange phenomenon as yet unexplained is the appearance of those lightnings which dart from time to time from certain caverns in the cliffs of the Norwegian coast. Between Bergen and Trondhjem, on the shores of the Jörend-fjord, rises Mount Troldjöl, or the rock of wonders. From time to time, though more often when the weather is about to change, columns of flame and smoke, followed by peals of thunder, escape from a lateral fissure of this mountain. But the cavern in which these mysterious storms are developed is so difficult of access that no one has yet entered it. Nor has an attempt yet been made to explore another "laboratory of tempests," occurring in the southern of the two cliffs at the entrance to the Lyse-fjord; this perpendicular wall is 3600 feet in height, and to reach the cavern it would be necessary to descend by means of ropes more than a thousand feet in the terrible abyss. From time to time, especially during a strong east wind, a flash of lightning is seen to shoot from the black rock, expanding and contracting alternately, till it is finally lost before having reached the northern cliff. The sheet of fire revolves as it advances, and it is to this rotatory movement that the apparent expansions and contractions of the lightning are due. Rapid detonations make themselves heard with increasing force before the flame darts from the rock; a violent peal of thunder accompanies it, reverberating with long-repeated echoes in the narrow glacier-formed corridor: one would think that a battery, placed in the cliff, was cannonading some invisible foe concealed in the opposite wall. Such were the strange phenomena of which the geographical engineer Krefting was the witness in 1855, during a topographical survey of the country. The inhabitants state that in fine weather, and when the wind has not blown from the south-east for several days, smoke of a yellowish grey colour is seen to issue from the cavern, and creep up the rock.

CHAPTER XLV.

POLAR AURORAS.

THE violent tempests which are so frequent in the temperate, and still more so in the tropical regions, form a most striking contrast to the long and silent atmospheric disturbances which make themselves apparent in darts of flame over the polar heavens. These are the Aurora Australis and the Aurora Borealis. When but slightly luminous they appear as a whitish or vaguely illuminated cloud in the direction of the pole, though often the existence of these phenomena can only be recognized by the sudden variations of the magnetic needle. These almost invisible polar auroras are frequent in the temperate zones, where we very rarely can contemplate the sight of the sheets of flame and rockets which give such magnificence to the Grand Northern Auroras. In central and southern Europe many persons pass their lives without ever witnessing one of these beautiful spectacles of nature. The only silent displays of terrestrial electricity which they have seen are those vague glimmers which often issue from the ground during dark nights. As Humboldt has observed, this telluric light is often sufficiently bright—especially in winter, when the ground is covered with snow—to enable one to discern the forms of objects at as great a distance as during twilight.

It is to Scotland, the Shetland Isles, Scandinavia, North America, or better still, to Lapland, the shores of Hudson's Bay, and the Polar islands, where long winter nights endure for several weeks, or even months, that we must go in order to contemplate these vast auroral displays in all their grandeur. In 1838 and 1839 a French scientific expedition, encamped on the shores of the Alten-fjord, under the 70th degree of north latitude, observed during 206 days 153 auroras, not reckoning six or seven phenomena of this kind which were doubtful; and 64 of these took place during the period of 70 nights, which intervened between the 17th of October, 1838, and the 25th of January, 1839; so that the members of the expedition came to expect the periodical return of these exhibitions as a matter of course. When the aurora was wanting, the sky was almost always covered in a great part with clouds.

Auroras first appear as a faint glimmer on the northern horizon, like an undecided daybreak. A large dark segment of black clouds, in which Bravais believed he recognized the mass of fogs which brood in the distance over the sea, spreads over the sky in the direction of the magnetic pole. Soon a curve of light shows itself above the thick stratum of vapours like an immense arch, spreading from one end of the earth to the other. The light, of a yellowish white hue, gains rapidly in brilliancy, without, however, extinguishing the luminosity of the stars,

which sparkle through it; it flashes, vibrates, and moves like a flame shaken by the wind; sometimes, too, it divides into symmetrical masses, appearing like the flaming openings of a building on fire, the façade of which has remained dark. Often a second luminous arch, and a third, or even several other more concentric arcs of fire, form above the first, and stretch up towards the heavens. For some time these arches of light alone illuminate space; then we suddenly see coloured rays flash from the arches to the zenith, in convergent pencils, green at the base, golden yellow at the centre, and a red purple at the extremity, succeeding each other regularly, thus adding to the splendour of the light by the most dazzling beauty of their colours; and often, according to Hansteen, black or dark violet rays alternate with the rings of light, thus rendering them more brilliant by contrast.

Fig. 142.—Elevation and Breadth of the Aurora Borealis of August 28th, 1859.

The beauty of the Aurora Borealis is due to the infinite variety of its changing forms even more than to its various colours. Now the two ends of the arch rise off the horizon, and the luminous sheet undulates and turns back upon itself like an immense fringed drapery; now the sheaves of rays, suddenly arrested, seem to unite in a golden cupola; often they are separated from one another as by columns of smoke, and the glimmering rays of the aurora are alternately extinguished and re-lighted. These rays, to which the Canadians give the name of "marionettes," or merry-dancers, vary incessantly in length and brilliancy; the earth itself, being almost always covered with snow during the time when the magnetic light is most frequent, appears now clearer, now darker, by contrast with the flaming rays. At the magnetic zenith, towards which the southern pole of the needle is directed, the sky appears dark; but all round it the divergent rays which come from the

northern horizon and spread farther and farther from each other towards the south, form a sort of crown. This is the most brilliant period of the phenomenon. Afterwards the splendour of the arches and rays diminishes gradually ; they are seen to flicker, so to speak, as if the stifled flame tried to revive, which is gradually extinguished, and there only remain here and there "auroral discs" emitting a feeble glimmer like the distant lightnings of a tempest; and then there only remains a vague phosphorescence on the whitish cirri. Usually the magnetic aurora completely ceases before the first faint glimpse of dawn begins to show itself on the eastern horizon.

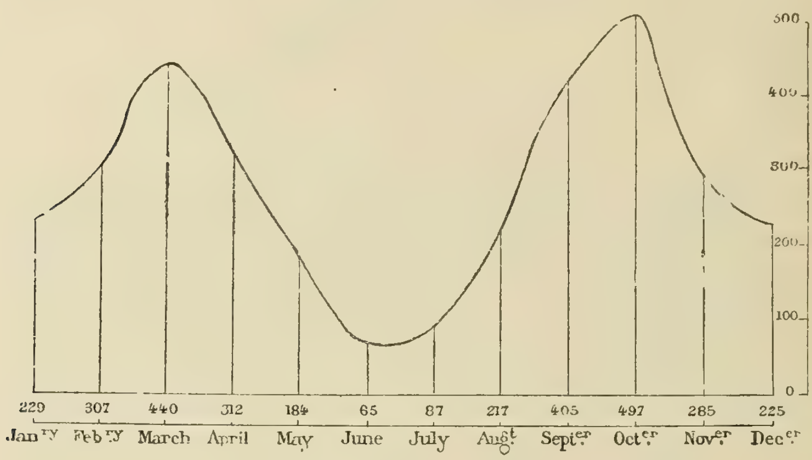
Most natural philosophers assign a considerable elevation to the polar auroras. They think that these phenomena are generally produced in a very rarefied medium

Fig. 143.—Elevation and Breadth of the Aurora Borealis of September 2nd, 1859.

towards the upper limit of the atmosphere, and one is inclined to consider this opinion as very probable, seeing the analogy which exists between the brilliant colours of the arcs and rays of the aurora, and of those caused by passing an electric current through a vacuum. After having confirmed Hansteen's idea that the northern auroras are not arches of light as they appear by an optical illusion, but really circles surrounding the magnetic pole, and radiating at the same time towards all the circumpolar regions of the Old and New World, Bravais attempted to measure their height, and calculated that it is on an average 95 miles above the surface of the earth. Later, Elias Loomis, one of the most distinguished physicists of North America, compared and thoroughly discussed all the observations recorded in various latitudes of the two magnificent auroras of the 28th August and 2nd September, 1859, and the result of his researches tends also to

prove that the mean elevation of the rays is very great. Thus, at the appearance of the former aurora the lower extremity of the columns was formed at 46 miles high, while their upper extremity attained the enormous height of 530 miles. The rays of the latter aurora extended upwards into the sky, from an elevation of 50 to 490 miles above the sea-level. By a like calculation of the height of thirty other auroras, it has been found that the extreme height reached by the rays is on an average 450 miles above the earth, and that the length of these brilliant rays is ordinarily about 400 miles. It is true that earlier observers have arrived at quite different results. Some even believed that, from the appearance of reflections in the clouds, certain auroras occur in the lower regions of air at no greater elevation than half a mile or a mile. On the shores of lake Scavig, in Scotland, rays have been seen to issue from a rock; but it is probable that these beams from below are secondary phenomena. However it may be, one cannot doubt that auroras have the atmosphere for their theatre, for they follow the general rotatory movement of the globe in its direction from west to east. The following figure indicates, according to the observations collected by Loomis, the position and

Fig. 144.—Monthly Distribution of the Aurora Borealis (after Kamtz).



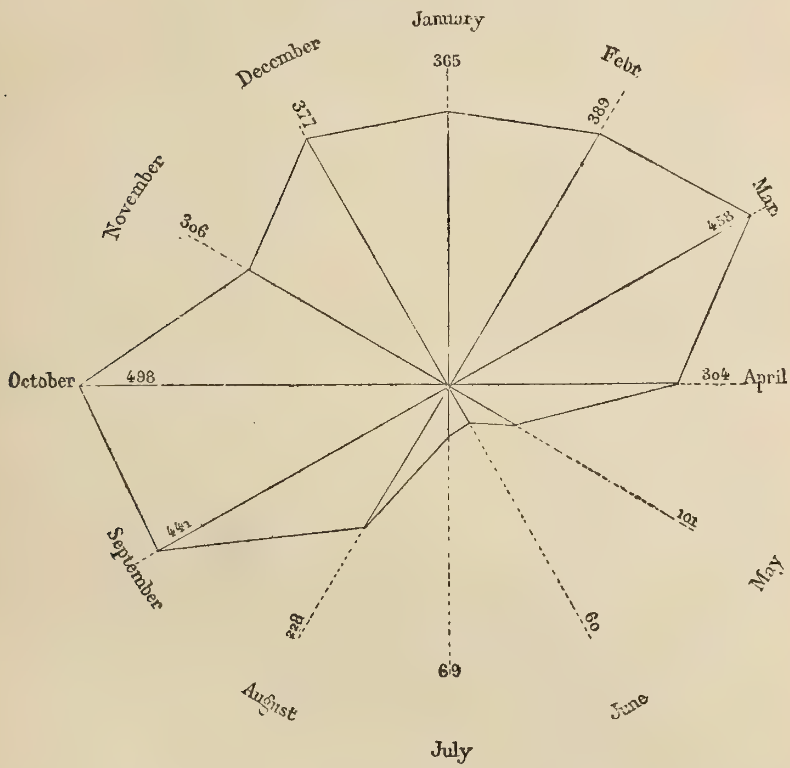
relative height of the Aurora Borealis of September 2nd, 1859, which shone with such brilliancy above the United States and Central America. The upper fringes of the most southern sheet appeared vertically above the ground in Florida at the latitude of 25 degrees 15 minutes, and the general inclination of the aurora was precisely that which a magnetic needle freely suspended would have had in the same region. The aurora which appeared four days before had its southern limit in Virginia towards 38 degrees 50 minutes of latitude.

The inhabitants of the north relate that auroras are often accompanied with detonations; nevertheless in no case has a scientific observer ever noticed the least sound which seemed due to them; for, as Becquerel has remarked, it would not be astonishing if the splitting of the plates of ice composing the cirri under the influence of the currents which traverse them caused a slight noise to be heard. It is, in fact, in an atmosphere full of ice-crystals that the aurora most frequently occurs, which can be observed immediately after the cessation of the phenomenon, by seeing that clouds formed of icy particles are exactly in the direction whence the most brilliant light flashed. As Loomis justly says, when one sees the light

flash, it is natural to listen for a report, and one often hears that which one wishes to hear. It is thus that the ancient Germans perceived the hissing of the sea when the setting sun, like a red-hot iron, sank into it.

An aurora may last for long time, even for a day or two, or even longer, for during the whole week which commenced August 28th, 1859, this phenomenon endured with greater or less intensity over the United States. In full daylight the disposition of the clouds and the restlessness of the magnetic needle revealed the invisible aurora. In 1786 Löwenorn even recognized after sunrise the luminous beams of an auroral light, so brilliant were they; but it is almost always during the night that this phenomenon takes place. The coloured rays which exercise such a great influence on the movements of the magnetic needle ordinarily appear

Fig. 145.—Monthly Distribution of the Aurora Borealis (after Klein).

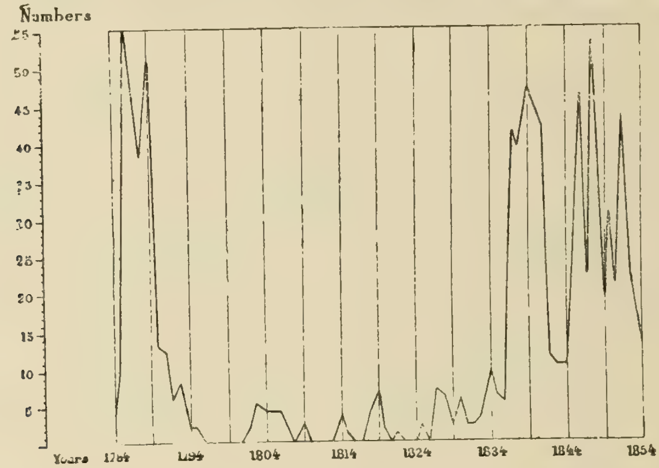


before ten o'clock in the evening, and are rarely perceived after four o'clock in the morning. Bravais affirms that the auroras which he witnessed in his polar expedition commenced on an average about 7 hours 52 minutes in the evening. It was then that the luminous arch extended over the sky, soon after the rays darted towards the zenith, the auroral discs appeared, and towards half-past three in the morning the last glimmers vanished. In the same way, it is during the winter, which is, so to speak, the night of the northern hemisphere, that the auroras advance to a greater distance to the south, and appear to the inhabitants of the temperate zone. The periods during which these magnetic disturbances most frequently occur are those of the equinoxes, at the commencement and end of the winter season. Meteoric phenomena of this kind are most scarce in the month of June. M. Boué, who has made a list of all the scientific observations of auroras up to 1860,

enumerates only 7 for the month of June, while no less than 458 have been recorded in March, and 498 in October, at the time of the equinoxes. The figure on page 286 may give some idea of the distribution of the auroras in the different months of the year. Figure 145, constructed on slightly different data, and according to a more logical method, as it represents the circle of the year, shows also that this is the average distribution of these aërial storms.

It is probable, whatever the meteorologist Glaisher may say, that the magnetic auroras have also their periodicity, like all the other phenomena of nature. This is established by the catalogue of observations made in Europe and North America from the end of the seventeenth century to our own time. In 1697 the auroras were not at all numerous, but they gradually became more numerous till 1728, and then diminished. In 1755 they were of very rare occurrence, but became more and more frequent towards the end of the century; in 1812 they were again at a minimum, but from the year 1825 they increased in number very rapidly, the average rising from 1 per annum to 30 and 40 in the same space of time. It would appear from the discussion of these facts that the cycle of auroras is one of

Fig. 146.—Auroras Observed at Newhaven, Connecticut, United States, 1784—1854.

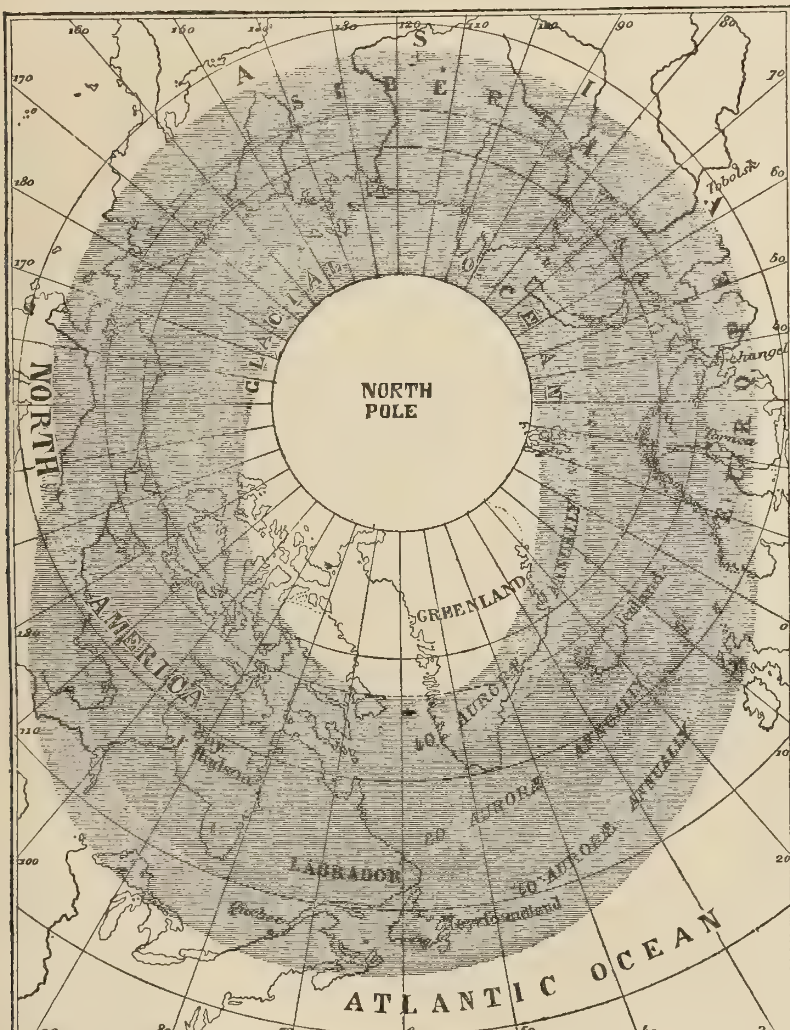


58, 59, or 60 years, and perhaps this period may itself be divided into six periods of ten years, corresponding, as Schwabe observes, with the regular variations of similar duration noticed in the number and size of the sun-spots; thus the fluctuations of the magnetic storms constitute an astronomical phenomenon. The accompanying figure represents the series of auroras seen at Newhaven in Connecticut, during the 70 years from 1785 to 1854, comprising an entire period.

It is difficult to explain now why the aurora appears more frequently in certain places of the Old and New World than in other parts situated at an equal distance from the magnetic pole. But it is incontestable that this latter point is not distant from the centre whence the auroral light radiates. In our hemisphere the culminating point of the luminous arc is found towards the direction of the peninsula of Boothia-Felix, where Ross saw the southern pole of the magnetic needle turn directly towards the centre of the earth. In Norway one sees the Aurora Borealis in the north-west; in Greenland directly to the west, at Melville Island Parry viewed it on the southern horizon. It must not be thought, however, that these magnetic storms are very frequent in the high circumpolar regions; on the

contrary, they are rather rare there, to judge from the accounts of travellers who have advanced farthest to the north. Hayes, during his stay in Smith's Sound, only saw three phenomena of this kind. In this northern space which is destitute of auroras—that is, in Southern Greenland, the Polar Archipelago, the North of Siberia, and Spitzbergen—there is a zone of 300 miles in diameter, where about forty times every year these northern lights are visible. The wider zone, which comprehends Hudson's Bay, Labrador, Iceland, and the north of Scandinavia, is

Fig. 147.—Circumpolar Zone of the Aurora Borealis.



richer, for eighty of them occur on an average yearly. Farther south extends a third zone, where these magnetic disturbances become less and less numerous; finally, in temperate regions these phenomena are rare, and towards the tropic of Cancer they are almost unknown. At Havannah only six auroras have been seen on the northern horizon in one hundred years. These magnetic storms very frequently extend over nearly all the northern hemisphere at the same time, thus being very different from thunder-storms, which are usually confined to limited

areas. The aurora of August 28th, 1859, was visible from California to the Ural Mountains, over a space of more than 150 degrees of longitude. That of four days later was seen at the Sandwich Islands, in the whole of North America, and in Europe; while at various stations in Siberia, where the sky was cloudy, the variations of the magnetic needle testified to the atmospheric disturbances. It was on this occasion that the simultaneous appearance of the aurora on the two sides of the earth was first noted, both in the skies of the northern hemisphere as well as above the Cape of Good Hope, Australia, and South America. At the same instant in Labrador, at Philadelphia, Edinburgh, Algeria, and Valparaiso, luminous streaks were seen to dart from the polar regions; the storm was visible over more than a half of the planet. Thus the theory of the meteorologists that the northern and southern auroras occur at the same time in both hemispheres under the influence of the same current, was confirmed. Of thirty-four auroras observed at Hobart Town in Tasmania, between the years 1841 and 1848, twenty-nine coincided with the occurrence of the same phenomena either in Europe or in North America, and all were marked by magnetic perturbations at the opposite pole. The fact, noticed by Forster, has since been confirmed by others, that the northern and southern auroras present remarkable contrasts in the colour of their rays, the light of the latter being of a pale blue, and less coloured than that of the arctic region, thus forming a parallel to the way in which the hues of the rays of light differ at the two poles of an electric current. It may be considered certain that the extremities of the earth are in intimate connection with one another through the electric and magnetic currents continually circulating between them, both in the air and the mass of the globe. The researches of M. Becquerel and other natural philosophers have shown that it is probable that the superior strata of the atmosphere are almost always charged with positive electricity, and the warmer strata reposing on the surface of the land and of the sea, with the opposite kind of electricity. In consequence of the enormous evaporation from seas under the tropics, the moisture charged with positive electricity, rising to the upper atmosphere, maintains it in a state of constant tension; but violent thunder-storms, accompanied by very abundant rain, constantly tend to restore the equilibrium. Away from the tropical zone the higher and lower strata, less strongly electrified, no longer by sudden discharges, but by the silent action of the polar auroras, the two contrary electricities meet and are neutralized. Such is the theory. In any case it is certain that the auroras are electrical phenomena, since they act on the wires of the telegraphs like voltaic batteries, and since the colours of the arcs, beams, and auroral rays are precisely those of the ordinary electric spark passing through rarefied air. At the same time auroras are magnetic phenomena, as is proved by their powerful action on the movements of the needle. Though produced in the atmosphere, and always accompanying the globe in its diurnal rotation, they are also very probably astronomical phenomena, obeying in their successive periods the cycles of the sun. Solar attraction, magnetism, electricity, are all convertible forces which work in concert to modify incessantly and then to re-establish the equilibrium of the atmosphere.

CHAPTER XLVI.

TERRESTRIAL MAGNETISM.—DECLINATION, INCLINATION, AND INTENSITY OF THE MOVEMENTS OF THE NEEDLE.—MAGNETIC POLES AND EQUATOR.—ISOGONAL LINES AND THEIR SECULAR ANNUAL AND DIURNAL VARIATIONS.—ISOCLINAL LINES.—ISODYNAMIC LINES.—EARTH CURRENTS.

THE incessant mobility so characteristic of all the phenomena of climate is most especially manifested in the perpetual oscillations of the electric currents. Magnetism, a force as mysterious as the nervous fluid of organized bodies, in its invisible undulations vibrating from the poles to the equator, transforms this planet into a gigantic load-stone. The heat of the sun, which gives life to our globe, causes a continual tremor in the crust of the earth; currents of electricity (whose incessant movement from east to west in an opposite direction to the rotation of the globe, was discovered by Ampère) vibrate round the terrestrial surface like an immense coil, and maintain between the two poles a magnetic activity exactly similar to that which is produced in an induction coil. All bodies are more or less influenced by these currents, and would arrange themselves in certain regular directions did not the bulk, weight, and cohesion of their particles hinder them from obeying the force acting upon them. The magnetic power of the earth is estimated by Gauss at 8464 trillion times that of our strongest artificial magnets, and yet this immense power has only been known for a comparatively short time. It was only in the year 1700 that Halley drew the first magnetic chart, and it is scarcely seven hundred years since the sailors of Amalfi, Provence, and Liguria learnt from the Arabs, or discovered for themselves, the movements of the magnetic needle, and this was the earliest recognition of this magnetic current pervading every atom of the planet. Chinese navigators had known the remarkable properties of the compass for more than two thousand years before this.

In the earliest times it was believed that the needle pointed constantly towards the polar star, or rather towards the pole of our planet; but the mariners who ventured as far as the Canaries and Iceland, or even those who confined their voyages to the Mediterranean, ascertained that the point of the compass did not invariably indicate the north, and that it diverged according to the latitudes by a greater or fewer number of degrees to the right or left of the normal direction. In 1268, Pierre Pélerin de Maricourt observed that it pointed 7½ degrees towards the east at Lucera in Southern Italy. Columbus, on the voyage in which he discovered the New World, also observed that the variation of the compass was several degrees to the west of the astronomical pole; and it is said that he was obliged to reassure his sailors, who were alarmed by this unexpected phenomenon. Finally, the expeditions of Magellan, Drake, and other circumnavigators of the globe,

established the greatest east and west variations of the needle from the north pole. These variations are known under the name of *declination*.

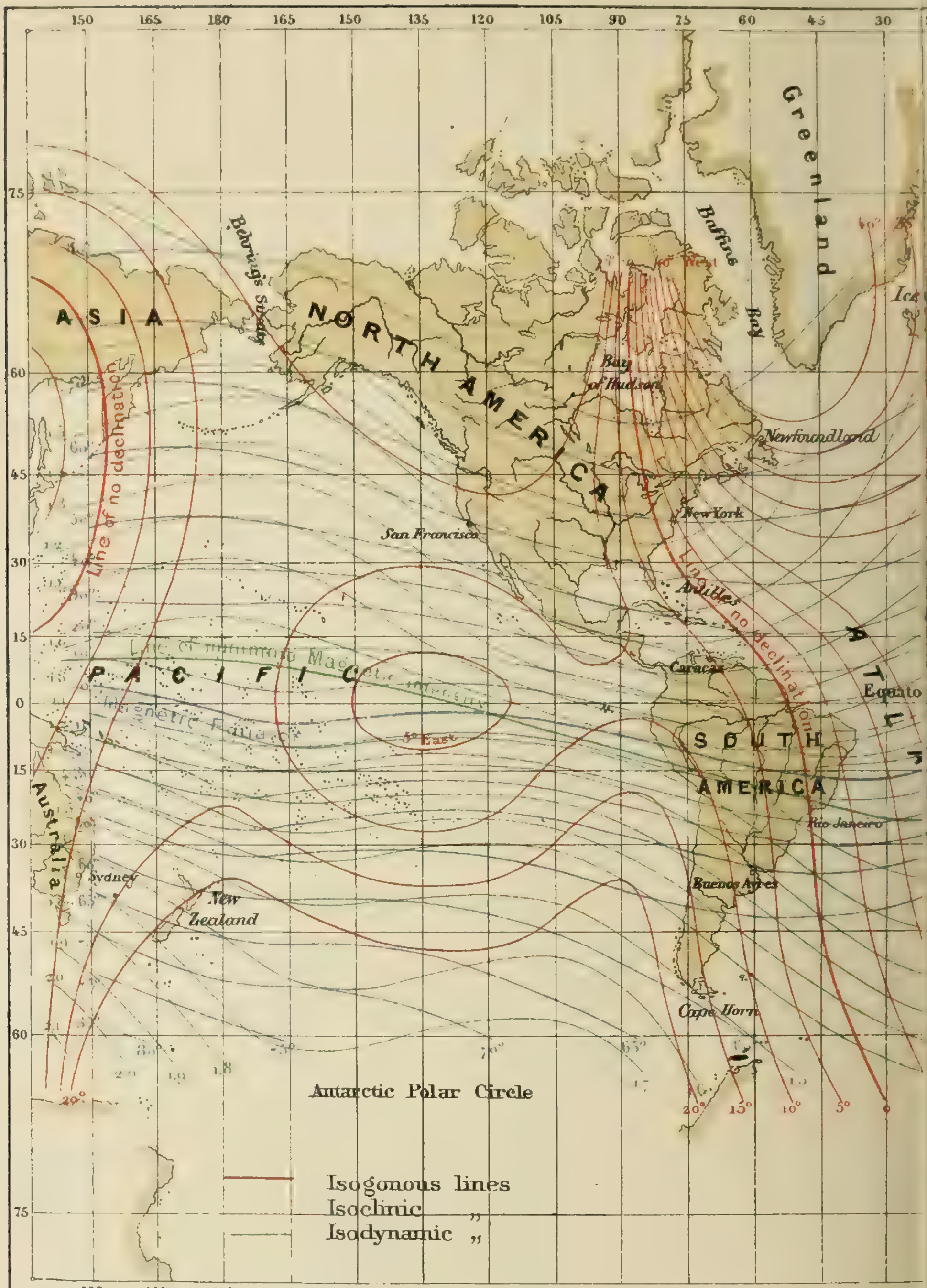
The deviation of the needle is not the only fact showing the magnetic action of the earth. In 1576 the Englishman Norman first noticed that the needle did not occupy a horizontal position in the latitude of Europe. On ascending towards the north magnetic pole, the northern end of the needle dips more and more to the ground, and directly over the pole it becomes vertical; while on the contrary, as we descend to the south the needle becomes less and less inclined to the surface, till, on reaching an imaginary line called the magnetic equator, it is parallel to the ground. Beyond this it inclines more and more in the reverse direction, till, on arriving at the southern magnetic pole, the needle again becomes vertical, though now of course with its southern pole towards the earth: this is the phenomenon designated by the name of *inclination*.

Nor is this all: if we cause the needle to diverge from its normal direction, in returning to it it oscillates more or less rapidly according to the part of the earth where we happen to be. These oscillations, analogous to those of the pendulum, reveal the greater or less intensity of the currents, according to the distance from either pole, just as the extent of declination and inclination varies. These local differences, however, are by no means permanent. The direction and force of the magnetic currents which are produced on the surface of the planet change continually from hour to hour, from day to day, from year to year and from cycle to cycle, conformably to laws of periodicity; but science as yet has not discovered all the elements. Among the grand manifestations of planetary life, of fluvial and marine currents, of the weight of the atmosphere, of the pressure of the vapour of water, of the alternations of the wind, of the variations of the climate, there are no phenomena which are more rapid and changeable in their alterations than those of terrestrial magnetism.

What is the probable cause of those currents which vibrate around the earth, and by which the compass is incessantly agitated, like the weathercock under the pressure of winds? The cause must be sought for not only in the movements of the earth, but equally in those of the sun, that great source of terrestrial life. The contrasting masses of earth and water, so unequally distributed in the two hemispheres, the difference of temperature between the aërial strata, the diurnal rotation of the planet around its axis, its annual revolution around the sun; the different rate of motion of the various parts of the surface of the globe, between the equator and the poles; the increase or diminution of its rapidity as it approaches or retires from the sun; the rotation of the sun; and finally the various periodical phenomena to which it is subject, its movement in space towards unknown regions of the heavens, the approach of a perturbing planet; everything, even the friction of the earth on the vapours which surround it, incessantly develops the magnetic energy of the globe, as an immense coil traversed by most powerful electric currents would do. In the ground which seems so impassive, but where so many germs give birth to life, whence so many wonders spring, the mysterious current circulates without ever resting, like an inexhaustible river. Under the influence of the sun it hastens or slackens its speed, moves in one direction or the other, and travels over the circumference of the globe, its equator and its poles. It obeys unceasingly the harmonious laws of nature, while only seeming to act capriciously because of the manifold interruptions causing the apparent irregularity in the succession of its periodicities. Just as the fine magnetic needle trembles and shakes like an affrighted creature in its box suspended at the ship's helm, so all over the earth

Ocean.

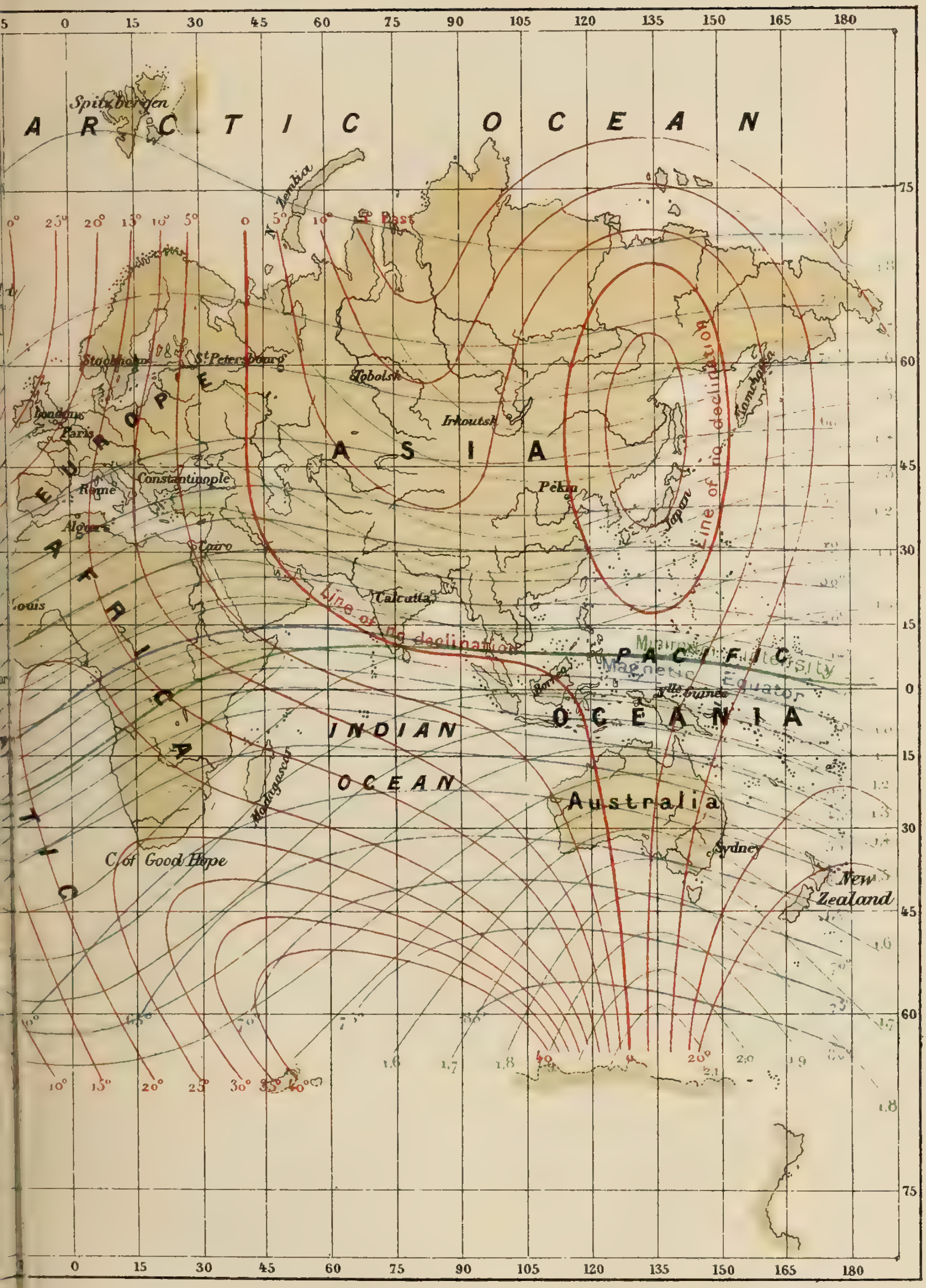
ISOGONOUS, ISOCLINIC & IS



LONDON, J.

: ISODYNAMIC LINES.

PL. XVII



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magnetic currents oscillate and move untiringly ; directly obeying the cosmical influences which make themselves only slowly felt on other functions of the globe, they may rightly be compared with the nervous phenomena in the animal organism. In consequence of their continual vibratory motion, the magnetic currents cannot be clearly traced on the map, and we must always confine ourselves to indicating their mean direction. There are not two instants in the year when the movements of the needle are identical on the surface of the earth.

The poles towards which the compass points in the two hemispheres stray constantly around the astronomical poles of the planet, and it is never at the same point that their precise position must be sought for. In 1832 Captain John Ross, then sailing in the midst of the polar archipelago of North America, arrived in the neighbourhood of the north pole of the compass, since the point of his instrument was directed almost vertically to the earth. This point, towards which all the magnetic currents of the northern hemisphere then converged, was situated in the peninsula of Boothia-Felix, nearly 20 degrees to the south of the terrestrial pole (70 degrees 5 minutes, north) and at more than 99 degrees to the west of the meridian of Paris ; but since that epoch it has probably moved a few degrees to the east. The magnetic pole of the south has not been discovered by any navigator up to the present time. But according to the calculations of Duperrey, Gauss, and other savants, it would probably be found at 14 degrees 55 minutes from the Antarctic pole to the south of the continent of Australia. The two points of attraction of the magnet are thus each situated at the meridian of a group of continents; but they are not antipodal to one another, since they are found in the same hemisphere separated from one another by an arc of little more than 161 degrees, 29 degrees less than the semi-circumference. As to the magnetic equator, which is the line where the needle keeps perfectly horizontal to the surface of the earth, it is no more to be confounded with the equator of rotation than the magnetic poles with the extremities of the planetary axis. It follows a curved line which cuts the terrestrial equator to the east of the Carolinas, traverses the islands of Sunda, Hindustan, Ethiopia, and Sudan, then passes to the south of the equinoctial line not far from the island of St. Thomas, and lies in America above Brazil and Peru. We may say generally that the magnetic equator curves towards the north in the continents of the Old World and towards the south in the New World. At the present time this line is slowly moving its points of intersection of the terrestrial equator from east to west.

The two magnetic poles occupy in relation to the earth's axis a position quite oblique, since one is situated in the American polar archipelago, while the other is found under the meridian of Australia. It results from this, that the currents are themselves propagated obliquely to the surface of the globe. Instead of advancing in the direction from north to south, the mysterious force moves according to curves not parallel, which on the Atlantic face of the earth bend towards the west, and on the opposite side for the most part diverge towards the east. The lines of separation between these two zones of western and eastern declination are the only parts of the earth where the compass points directly to the north. In order to indicate clearly the average direction of the magnetic needle for any year whatever in various countries, other lines, called *isogones*, are drawn on the map to the right and left of those marking no declination, where the compass forms one and the same angle with the terrestrial meridian. These curves, connecting all the points of the earth where the mean inclination of the needle remains sensibly equal, are much less regular than the magnetic meridians. Some are directed from the north

to the south, others run partly from the east to the west; others again bend in the form of circles and ovals.

At present, the line without declination which traverses the ancient world passes to the east of Spitzbergen, touches Russia in the environs of Archangel, gains the Caspian depression by the valley of the Volga, crosses Persia obliquely, then after having coasted Hindustan and the islands of Sunda, as if to mark the general outlines of the Asiatic continent, it is directed abruptly towards the southern magnetic pole across the centre of Australia. To the west of this line, as far as the other side of the shores of the continental group which constitutes Europe and Africa, the declination of the compass towards the west increases gradually, and then diminishes above the basin of the Atlantic, and is reduced to zero on the eastern coasts of the New World. The second line without declination, which one might call the American line, descends from the magnetic pole to the west of Hudson's Bay, traverses the great lakes, passes the environs of Philadelphia and Washington, and then curves round the Antilles, as the other line without declination is curved around the archipelago of Sunda, and cuts the extremity of Brazil from the mouths of the Amazon to Rio de Janeiro, and crosses the Atlantic towards the south pole. To the west of this line the deviation of the compass becomes easterly, increasing rapidly above America, then much more slowly across the Pacific, and diminishing to the east of China and Siberia, so as to enclose a kind of magnetic island where the declination is western, as in the basin of the Atlantic. Whatever may be the partial irregularities of these two zones of different variation, it is impossible not to be struck by their general agreement with the most salient features of the planetary surface. The basins of the Atlantic, the Mediterranean, and the Indian Ocean, correspond with the western declination, and the Pacific corresponds with the eastern declination. Four continents, Asia, Australia, North and South America, belong to this latter zone; while Europe and Africa, form part of the zone of western declination.

During the course of centuries the system of isogonal lines moves very rapidly in certain countries. In the seas of Spitzbergen, to the west of the Antilles, in various regions of China, the mean direction of the needle has not varied in a perceptible manner for a century: but it is not the same in western Europe. At Paris, at the time of the first regular observations on terrestrial magnetism, the declination of the compass was easterly; it even reached in 1580, 11° 31′ to the east of the meridian. In 1663 the declination existed neither in one direction nor the other, the magnetic needle was directed exactly towards the north. From that time the declination towards the west continued to increase during more than a century and a half, till 1814, when the angle formed by the needle with the terrestrial meridian was not less than 22° 34′. Since then the needle has retrograded towards the meridian, and in the year 1864 the angle was only 18° 30′. The recoil is thus on an average nearly five minutes per year, but it changes in a very irregular manner, for in certain years the western declination has suddenly increased again. We cannot doubt that these secular oscillations of the magnetic current make part of a cycle, the duration of which corresponds with that of some great astronomical phenomena. According to M. Chazallon, this period would be for Paris 488 years, and the magnetic needle would be again directed exactly towards the north in the year 2151. The line without declination moves little by little from the confines of Russia, and will successively traverse Poland, Germany, and France, then passing above the Atlantic, it will later commence its return towards the east. Notwithstanding this secular balance of the magnetic forces, it

is probable, however, that as a whole, the currents never end by following exactly the same directions on the surface of the earth; the poles, the equator, the meridians moving incessantly, the network of magnetic lines changes eternally, like the relative position of the stars in space.

While this long secular variation is accomplished, the needle is ever agitated by oscillations of shorter periods. Those which are completed in the course of a year are evidently connected with the position of the earth relatively to the sun, for its various phases coincide with the equinoxes and the solstices. In western Europe, as Cassini first ascertained, the compass gradually approaches the meridian, advancing towards the east, during the period which elapses from the equinox of March to the summer solstice; then the magnetic needle again advances towards the west, but slackening its march little by little, it is only at the end of winter that it attains its greatest declination towards the west: the return to the point of departure employs three-quarters of a year. In America the progress is different, which doubtless results from the difference of declination. The total extent of the annual variations presents a great irregularity: in 1784 it was about 20 minutes at Paris.

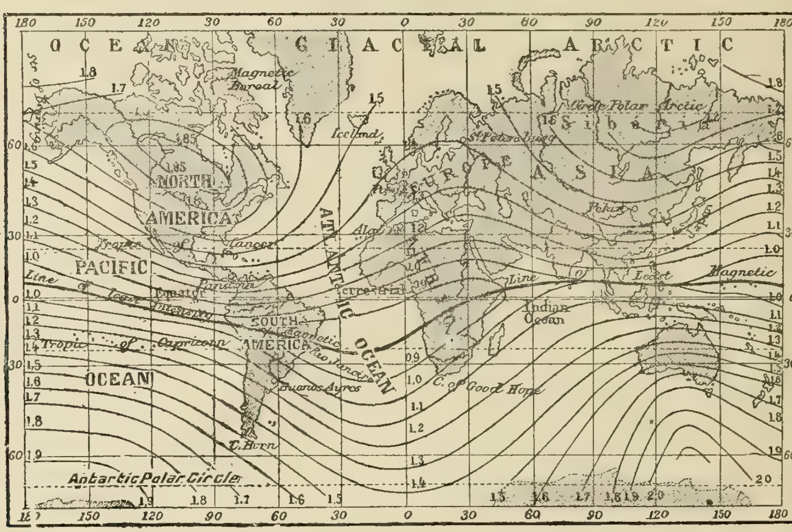
The diurnal variations differ also on all points of the earth. In France, where the amplitude observed oscillates between 5 and 25 minutes, the needle moves from east to west between 8 o'clock in the morning and 1 o'clock in the afternoon; it then returns to the east, and towards 10 o'clock it occupies nearly the same position as in the morning. In countries near the southern pole the extent of the diurnal variations is generally greater than in the temperate zone; in the torrid regions, on the contrary, these variations are slighter, while in the southern lands the diurnal movements become more and more considerable towards the south. As there they occur in the inverse order to those observed in the north, it is probable that the two hemispheres with opposite variations are separated from one another by a line where the compass remains immovable; however, this equator without variations has not yet been discovered with certainty, and in all probability would not agree with the magnetic equator.

In the same way as isogonal lines have been traced on the globe to indicate the declination of the compass in different years, so by the *isoclines* succeeding one another on each side of the magnetic equator, those parts of the earth are indicated where the magnetic needle dips towards the ground at the same angle. These isoclinal lines are in general more regular in their curves than the isogonal lines; but they also are influenced by the forms of the continents. It is principally in the northern hemisphere that this difference is shown. Thus the isocline of 50 degrees coasts the shores of Central America, then, after having crossed the basin of the Atlantic, traverses obliquely the depressions of the Sahara, the eastern Mediterranean, the Caspian, and turns northwards round the great mountains of Tibet. The isoclinal line of 70 degrees is developed off the western shores of North America from the peninsula of Alaska to the coasts of Oregon, while in the Old World it follows the depression formed by the Channel, the North Sea, the Baltic, and the Gulf of Finland. Finally, the line of 80 degrees follows at a distance the polar shores of America, runs afterwards along the eastern coasts of Labrador and Greenland, and bends in an immense curve round Scandinavia. Like all the other magnetic phenomena, the inclination is subject also to incessant variations, periodical and accidental, but these variations have been less studied than those of declination. At Paris the needle has become less and less inclined since 1671, when it dipped 75 degrees, while in 1864 it was only 66 degrees

3 minutes; the annual diminution has thus been a little more than 3 minutes. Observations made at London, and in several other towns of western Europe, lead us to the same result. As to the monthly variations, they are less relatively than those of declination; it is in summer that they have the greatest amplitude.

The isodynamic lines, that is to say, those which unite the points of the earth where the movements of the magnetic needle have an equal intensity, for the greater part resemble in their curves the isoclinal lines; nevertheless they do not coincide with them. The dynamic equator, a line where the intensity of terrestrial magnetism is manifested with the least force, is also inflected in the southern hemisphere, traversing Peru and Brazil, not far from Rio de Janeiro, and then ascending obliquely by the African continent towards the southern peninsulas of Asia and the archipelago of Sunda; on this equator the movements of the needle are slowest in the Atlantic off the Brazilian coasts. On each side of the line of the least force, the magnetic intensity increases towards the north and south, but

Fig. 148.—Isodynamic Lines.



in an unequal manner, since the isodynamic line of Florida bends to the north as far as Scandinavia, and that of South Carolina traces the outline of the American shores, and passes into Greenland. In the southern regions there only exists a single dynamic pole, situated at more than 16 degrees from the planetary pole, in the neighbourhood of the icy mountains discovered by Sir James Ross. It is there that the movements of the compass have the most intensity, and they are nearly three times more rapid than in the Brazilian seas. In the north there are two dynamic poles, one to the west of Hudson's Bay, the other to the north of Siberia, not far from the mouths of the Lena. In the same way as the isothermal lines, with which they have besides a great analogy, the lines of equal intensity have their two poles occupying a symmetrical position, the one to the north of the Old World, the other to the north of the New. Thus, as Duperrey remarks, this resemblance of the isothermal and isodynamic lines is a proof of the intimate connection which exists between terrestrial magnetism and temperature.

Recently M. Blavier, of the French High School of Telegraphy, has devoted

special attention to the subject of earth currents, which are a constant source of disturbance in the transmission of telegraphic messages, and which appear to be always present in the wires. They vary greatly in geographical and electric direction and in strength, being for the most part scarcely perceptible, but sometimes acquiring such intensity as to deserve the title of "storms." Their direction depends upon the direction of their earth terminals, and in no way on the route of the wires or on the fact of their being overground or underground. The longer the line the greater their strength. Their strength and direction vary with the hours of the day, and they show well-marked periods of maxima and minima. In fact, there appears to be a tide in their affairs clearly following solar influence, and it has been believed by more than one observer that the influence of the moon is also perceptible. There is also an annual period of maximum and minimum, and this follows the well-marked eleven-year period of sunspots. We have lately passed through a period of maximum intensity: 1881 and 1882 were years of considerable activity. Their vagaries are exactly coincident with the variations of the mariner's compass, and are evidently primarily due to the same cause. It is when the aurora is present that they acquire extraordinary energy, and change their direction and intensity with great rapidity. Their effects are then observable simultaneously over the whole globe. They interfere seriously with the transmission of telegraph messages. M. Blavier concludes from the deflections of the needles that the disturbances of the magnetic elements are due to accidental electric currents circulating in the higher regions of the atmosphere, although the earth currents circulate in the crust of the globe. He favours De la Rive's theory of the aurora borealis as being due to the circulation of electric currents in the higher regions of the atmosphere, in support of which he mentions several atmospheric effects well recorded as simultaneous with earth currents, such as intense scintillation of the stars observed by Montigny, and tempests. He associates earth currents with trade-winds, and thereby indirectly with the sun.

According to Dr. Wild, of the Pavlovsk Observatory, the terrestrial currents altogether do not manifest themselves as currents, which would flow for a time in one direction and then would slowly change it, but in the shape of more or less strong alternate currents, which rapidly change their direction. The east and west force is generally stronger than that of north and south. The observations on the regulation days do not show any diurnal periodicity, neither in the force of the current nor in the number of oscillations; but the average of the twenty-four regulation days of the year (September 1882 to September 1883) disclose such a periodicity, however feeble, namely, a maximum between 4 and 5 a.m. and a minimum at 8 p.m. for the meridional line, as also a maximum at 8 a.m. and a minimum at 1 p.m. for the other line. As soon as the force of the terrestrial current is on the increase, the magnetical instruments display perturbations which usually increase with the force of the terrestrial currents, without being, however, proportionate to them. If, according to Sir G. B. Airy, the north and south current be compared with the variations of declination, and the other current with horizontal intensity, both perturbations are often very equal, but those of the currents precede those of the terrestrial magnetism by at least five minutes. This retardation may explain the want of proportion between the variations of the current and those of the terrestrial magnetism, which proportion is the more wanting as the variations of the current are frequent and alternate. From these alternations Dr. Wild concludes that "terrestrial currents are always the primary cause of magnetic perturbations, but not of periodical variations of the magnetic elements."

CHAPTER XLVII.

SOLAR HEAT.—IRREGULARITIES OF LOCAL CLIMATES.—EQUALIZATION OF THE TEMPERATURE BELOW THE SURFACE OF THE GROUND.

ALL the facts of physical geography, the relief of continents and islands, the height and direction of the systems of mountains, the extent of forests, savannahs, and cultivated lands, the width of valleys, the abundance of rivers, the outline of the coasts, the marine currents, winds and all the meteoric phenomena of the atmosphere, vapours, fogs, clouds, rains, lightnings, and thunders, magnetic currents, or, as Hippocrates said more briefly, "the places, the waters, and the airs," constitute in their connection with longitude and latitude what is called the climate of a country.

The most important climatic phenomena are those of temperature, for it is to heat that most of the meteoric phenomena, in their various alternations on the surface of continents and seas, are due. It is the overheated regions which put in motion the whole system of atmospheric currents, and it is they too which give to the winds the moisture destined to be dispersed in clouds and to fall far away in snow and rain. By their action on the earth and on the waters, the rays of the sun give the first impulse to all that moves on the surface of the globe. It is on this luminous body that the life of our planet depends.

The earth has, it is true, its own heat, like all bodies in space; but whatever may be the unknown heat of its deeper strata, that of the surface results solely from the great source of heat, the centre of our planetary system. When the sun rises above the horizon the earth is warmed by its rays, but cools during the night by the radiation into space of the heat received during the day. The oscillations of relative heat and cold that we experience from day to night, and from summer to winter, all depend on the laws regulating the absorption and radiation of heat given off by the sun to the earth, or by the earth into interstellar space. It is these incessant alternations that the thermometer measures; since the heat of the air and the ground vary at all times and in all places, the series of temperatures which succeed each other in various localities, or even in one single place, become, so to say, infinite; and if we wish to keep an account of the phenomena of heat and cold, it is necessary to obtain, by comparison of instruments at regular hours and periods, the averages of diurnal, monthly, and annual temperature. This is one of the most difficult tasks, for we must first remove all possible chances of error, and choose for the place of observation precisely one where the indications of the thermometer are never modified by special causes, such as currents of air or radiated heat. The disturbing influences are so numerous that we are not yet sure of

having determined exactly the true average temperature of a city like Paris, where millions of observations have been made. M. Renon even affirms that for a hundred years meteorologists have always given by mistake a temperature too high by almost two degrees F. to the atmosphere of Paris. The use of automatic instruments which trace on paper, either by a pencil or by photography, the continuous series of curves produced by the oscillations of temperature, will diminish many probable errors, and singularly facilitate the comparison of all the results obtained in different localities.

If the earth were a globe of perfect regularity, presenting on its surface no contrast of land and sea, plateaux and plains, snow and verdure, and keeping always at the same distance from the sun, a natural distribution of climates would be established over the whole circumference of the earth, and one could exactly measure the degree of heat by the latitude. At the equator the temperature would be at its maximum, and from each side of this line decrease to the poles; thus, as the mathematician Lambert calculated, the total quantity of heat received as 1000 under the equator would not be more than 923 under each tropic and 500 under the polar circle.

But the earth is not an accurate sphere lighted in an always equal manner by the rays of the sun. It is illuminated in a different manner according to the seasons; and the features of its surface, harmonious as they may be as a whole, have not the perfect symmetry of geometrical figures. From this results an infinite variety of climate. One country near the polar circle receives more warmth than another situated at a less distance from the tropics; one region of the temperate zone is hot in comparison with certain spaces in the equatorial zone. The temperature continually varies, oscillates, and changes under the action of winds, currents, meteoric phenomena, and vegetation; and when indicated by lines on the surface of the earth, an inextricable network is formed of which we can only recognize the principal traits. Every season, every day, every minute still adds to the entanglement of these various temperatures, for nowhere do the periodical evolutions of local climates resemble each other in a perfect manner. In mountainous districts especially, the least difference of exposure or height causes the temperature of two neighbouring places to vary as much as if they were separated from each other by hundreds of miles. Beside the wintering towns on the coast-line of Provence and the Maritime Alps, Cannes, Antibes, Villefranche, which are well sheltered by an amphitheatre of hills, the sterile valleys of the Var, the Loup, and the Siagne open, like fractures of the terrestrial crust, making a passage for the terrible mistral, which was formerly said to have contributed more than Marius to chase the Cimbri from Gaul. The various lines of equal temperature which meteorologists have attempted to trace upon maps can never indicate more than general averages, through all the extreme lines moving incessantly from one side to the other like vibrating cords. And if the mean temperature of a single place is so difficult to know in an exact manner, how much more difficult to determine with precision for the whole of a country, the general climate resulting from the combination of all the particular climates.

Numerous observations made in different parts of the earth have demonstrated that the mean temperature, so difficult to ascertain with certainty on the surface, is constant at a variable depth in the earth itself. For as the solid strata composing the exterior of the globe conduct heat but very slowly, neither the solar influence can penetrate far inwards nor the internal heat radiate outwards, wherefore the variations of atmospheric temperature must be gradually diminished, or even

entirely obliterated, at a certain distance from the surface. On an average the heat of the day is propagated within the ground so slowly that in nine hours it only traverses the first superficial layer of one foot in thickness. At depths varying from 2 to 5 feet all the diurnal variations of heat completely disappear in the temperate zone. The annual variations, much more durable in their effects, penetrate to a greater depth; but in consequence of the earth being so bad a conductor of heat, it is found that at a few yards below the surface the order of the seasons is changed; the summer heat, so much retarded as it penetrates into the ground, only reaches the layers from 20 to 25 feet deep on the return of winter; on the other hand, the cold does not make itself felt in these depths till the middle of summer. The surface temperature takes no less than a whole month to traverse a layer of earth 3 feet thick, and in so slow a passage it ever tends to approach the annual average. At Brussels, the maximum heat having been felt on the surface on the 22nd of July, only attained the depth of 26 feet on the 12th of December following, 147 days later; in the same way the interval between the cold on the surface on January 23rd and that of the deep stratum on June 18th was 143 days; while the total annual variation of the temperature, which is about 35 degrees on the surface in this town, is less than 2 degrees at 26 feet below.

The complete neutralization of the influence of the seasons occurs at different depths. In the cellars of the Observatory of Paris, situated at 90 feet below the ground, the temperature is constant and is always maintained at 53 degrees. On an average it may be considered that in the north of Europe all the exterior influences of heat and cold have completely disappeared at 78 feet below the surface. The better conductors the underlying beds are, and the more porous they are, allowing air to penetrate from the surface, the greater and more rapid are the penetration and radiation of heat. Experiments made at Edinburgh by Forbes show that carboniferous sandstone is one of the rocks which best conducts heat, for the equilibrium of temperature is only found at a depth of 105 feet. In countries where the annual difference between the heat of summer and cold of winter is very great, it is relatively very low in the ground that we must search for the point where all the annual variations are neutralized. On the other hand, in those countries where the temperature of the various seasons hardly differs, it is only about a foot from the surface that the equalization of the annual temperature is established. M. Boussingault has ascertained that in order to know the annual temperature of New Granada and Ecuador, it is sufficient in certain places to introduce the thermometer from $1\frac{1}{2}$ to 2 feet into the ground. Under the polar climates, where the mean temperature of the atmosphere is below freezing point, the few observations that have been made seem also to establish the fact that the zone of neutralization of exterior influences is nearer the surface than under temperate climates: in certain parts of British North America it is said to have a depth of only 9 to 15 feet. At Yakutsk, where the average is 12° F., the same temperature is found at less than 50 feet; below this the ground becomes less cold, owing to the internal heat of the earth; and between 530 and 650 feet the sounding instruments would doubtless arrive at layers of earth which are not frozen. In the Chukchi country beds of ice were found alternating with sand and clay deposits, and containing the remains of whales, which no longer frequent the neighbouring waters. These beds which never melt, may be regarded as real geological formations. In the territory of Alaska, north of Behring's Strait, Dall has lately explored some hills consisting entirely of alternate ice and clay deposits, and containing the remains of shell-fish older than the present geological epoch.

Ocean. ISOTHERMALS OF

LONDON, J. S. VI

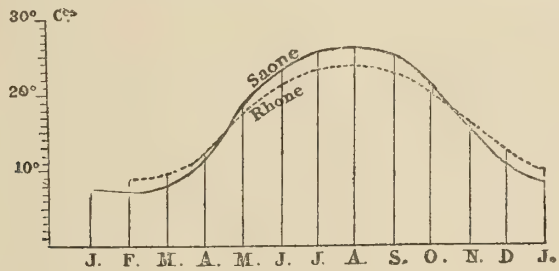

Polar Circle
NORTH AMERICA
Hudson's Bay
Davis's Straits
Rocky Mts.
Missouri R.
St Laurence R.
Newfoundland
UNITED STATES
New-York
St Francisco
New Orleans
Gulf of Mexico
Antilles
Sandwich
Mexico
Guatemala
Caribbean Sea
Panama
Is. Galapagos
Amazon R.
SOUTH AMERICA
BRAZIL
Nouka-hiva
Tuamotou
Lima
PERU
Cordillera of the Andes
Rio Janeiro
ATLANTIC
Santiago
Buenos Ayres
R. de la Plata
Falkland
Cape Horn
Shetland
Circle

E & Co LIMITED

The constantly frozen ground is the chief cause why cereals cannot be cultivated in Siberia beyond the latitude of Yakutsk (62 degrees N.). The temperature of the soil in which the roots vegetate varies between 36° and 41°. Thus, although the mean temperature at Yakutsk is 57° in June and 62° in July, the vegetation is relatively slow, while its period is ten to twelve weeks, as in Central Europe. The same period is observed in North America for barley at Fort Simpson (63° F.), where wheat never ripens at all. But harvests of thirty to forty times the amount of what was sown alternate in this climate with years of no harvest. The native plants, however, are known to withstand the lowest temperatures of the Siberian winters.

Springs, like the soil, often show the average temperature of a country, owing to their source in the cavities of the rocks. Indeed, by placing a thermometer in the basins of springs, travellers can ascertain the average climate of the regions

Fig. 149.—Ordinary Temperatures of the Saone and the Rhone at Lyons.



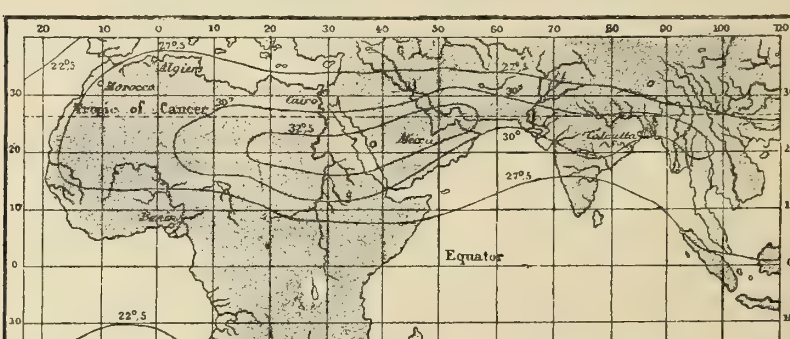
through which they pass. Observations of this kind are of great use, but they cannot replace long and patient study of atmospheric heat. One spring is on an average colder than the surrounding air, because its waters are produced by the melting of snows, or arise from rains that fell on the slopes of high mountains; another spring, slightly thermal, has traversed deep channels, where its temperature is raised by the telluric heat; another has passed through fissures which are chilled or warmed by currents of air circulating in the caverns of the mountains. The slight alternations of heat and cold occurring in springs are analogous to those observed in the waters of rivers. Watercourses, always cooler in summer and warmer in winter, have a temperature all the more equal the greater their velocity, because they are subject during less time to the changing atmospheric influences. Thus at Lyons, above the confluence of the two rivers, the fluctuations of temperature during various months of the year are 7 degrees less in the furious Rhone than in the peaceful Saone.

CHAPTER XLVIII.

CONTRAST BETWEEN THE CLIMATES OF THE NORTHERN AND SOUTHERN HEMISPHERES, BETWEEN THOSE OF THE EASTERN AND WESTERN SIDES OF CONTINENTS, THOSE OF THE COASTS AND THE INTERIOR OF COUNTRIES, AND OF MOUNTAINS AND PLAINS.

ONE of the most important climatic facts is that of the unequal distribution of heat in the two hemispheres. The observations made to the south of the equator during a long series of years are not sufficiently numerous for it to be possible to state a contrast of climate for each corresponding latitude of the two halves of the globe. But, taken as a whole, the northern and the southern hemispheres certainly differ in a remarkable way. This is proved by the immense size of the Antarctic ice-fields compared to the dimensions of those to the north, and the long

Fig 150.—DISTRIBUTION OF TEMPERATURES IN JULY.

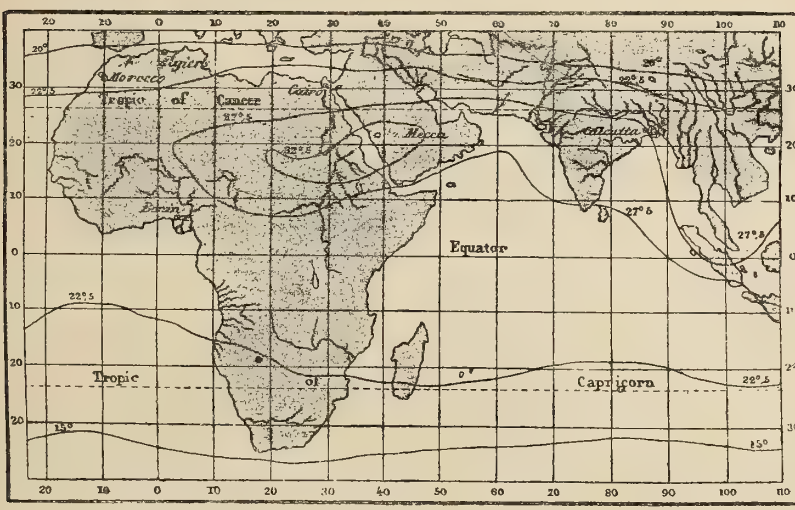


distances traversed by the flotillas of the former in their march towards the equator. The system of climates, like that of winds and currents, is drawn towards the north, consequently the line of highest temperature which separates the two hemispheres is not identical with the equinoctial line, but is thrown more to the north ; indeed, the thermal equator of the earth passes through the desert of the Sahara towards the twentieth degree of north latitude. During the spring and autumn, as well as

during the summer of the northern hemisphere, the greatest heat makes itself felt not only to the north of the equinoctial line, but also to the north of the 12th degree of latitude. It is only during the winter of Europe and Asia that the zone of greatest heat occupies the equatorial regions, and even then it is to the north of the equator, in Africa, especially the mouths of the Niger, where the highest temperature is preserved. The disproportion which exists between the continental masses situated to the north of the thermal equator and those which stretch to the south is thus much less than it seems at first.

It is probable that the first cause of this climatic contrast between the continental and the maritime hemisphere is of an astronomical nature, and ought to be sought for in the difference of relief presented by the two halves of the planetary orbit. The spring and summer of the northern regions are longer than the corresponding seasons of the southern countries. It is true that during the warm season of the northern hemisphere the earth is farther removed from the sun, and draws nearer to it during the period which is autumn and winter for Europe and Asia.

Fig. 151.—Distribution of Temperatures in October

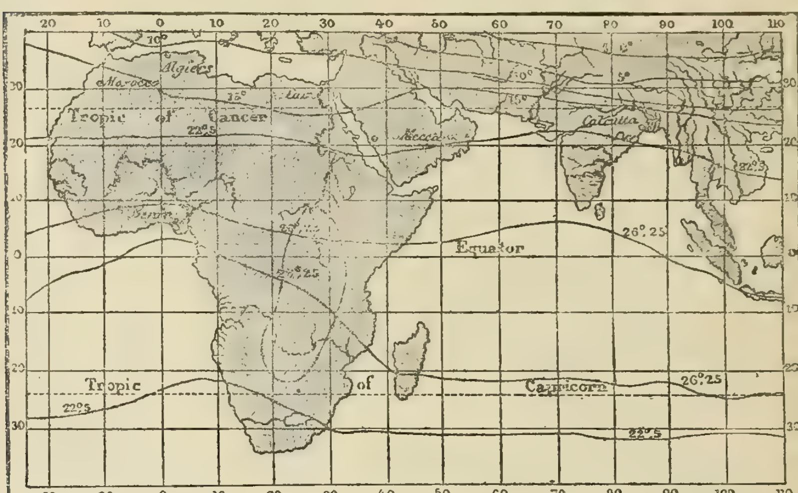


A compensation may therefore be produced in the two hemispheres for the total quantity of heat received, but in consequence of the inclination of the planet on its axis, it is also found that the number of hours of daylight is actually greater than that of the hours of the night to the north of the equator, while to the south it is the hours of the night which predominate. It results from this, that the northern countries receive more heat during the days than they lose by radiation in the nights, and that the inverse phenomenon obtains in the southern regions. The real result of all these contrasts between the two hemispheres is not yet clearly established, but it is not to be doubted that it constitutes a difference, either periodical or permanent, between the general climates of the two halves of the earth. According to Dove, the mean temperature would be 80° F. at the 10th degree of north latitude, and only 78 degrees at the corresponding south latitude: at the 20th degree the averages would be respectively 77·5 degrees and 74 degrees; at the 30th and 40th degrees of the two hemispheres there would still be a slight difference to the advantage of the northern temperatures.

According to Duperrey, there is a difference of about 1·8 degrees in the mean temperature of the two halves of the earth.

Among the secondary causes which must result in rendering the climate of the northern hemisphere a little warmer than that of the southern, we must reckon the distribution of rain. Considered in a general manner, the seas of the south are the area of evaporation, the continents of the north that of precipitation. When the water of the ocean is transformed into vapour, a great quantity of caloric becomes latent and is borne away with the clouds, the particles of which it dilates; with them it traverses the equator, and is carried away by the counter trade-winds; then, when the latter sink on the temperate regions of Europe and North America, the clouds descend also, and are resolved into snow or rain, when all the latent heat from the Pacific or Indian Oceans, stored up in the vapours, disengages itself and softens the temperature of the air, where it becomes free. Thus by the very fact of their existence, the continents of the northern hemisphere attract to themselves the heat and moisture necessary to the development of the animals and plants

Fig. 152.—Distribution of Temperatures in January.



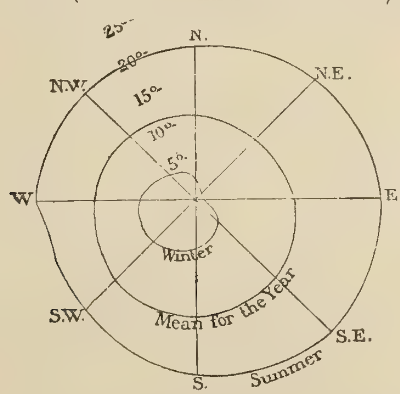
inhabiting them; but they also experience greater extremes of temperature than those of the southern hemisphere, where the immense extent of ocean moderates the intense cold and great heat.

If there is a contrast of temperature between the north and south of the world, the opposition is not less marked between the east and west of continents. On the same latitude the coasts of California and Oregon enjoy a much milder climate than those of Japan, Manchuria, and Nicolayevsk; while in western Europe the atmosphere is as temperate as that of the eastern coasts of North America 20 degrees of latitude nearer the equator.

The causes which thus soften the climate of the western shores in the two great continental masses of the north are due undoubtedly to the atmospheric and marine currents. The northern Atlantic and Pacific have each their Gulf-stream, and winds from the south-west, and these two superposed currents constantly discharge their warmth on the shores washed by their waves. Europe is especially favoured in this respect: not only is it warmed on the west by currents of water and counter

trade-winds coming from the equator, but owing to the larger extent of water to the north of the continent, from the tropical seas having a great coast-line washed by the waves, it is less chilled by the polar winds than North America, whose seas are blocked by snowy islands. Whilst Labrador and Hudson's Bay territory have a soil that is frozen to a great depth, Northern Europe projects its islands and peninsulas into water incessantly renewed by the tepid currents from the south, and its inland seas open like so many reservoirs to maintain to the centre of the continent a temperature equal to that of the outer shores. Nor is this all: immediately to the south of Mauritania extends the immense furnace of the Sahara, which warms by its winds the countries of Europe and western Asia. Thus in respect of climate Europe enjoys a special privilege. The north, the west, and the south all aid in the task of raising the mean temperature, and during summer all the surrounding seas store up heat to exhale it gradually during the winter. The east, however, sometimes sends its dry winds, very hot in summer and intensely cold in winter; but the Scandinavian mountains, the Sudetes, the Carpathians, and the Alps, rise like barriers across the path of these winds, and shelter western Europe. We may form an idea of the influence of the winds on the climates of

Fig. 153.—Variation of the Temperature at Paris, during the Prevalence of Different Winds (after Mahlmann and Lalanne).

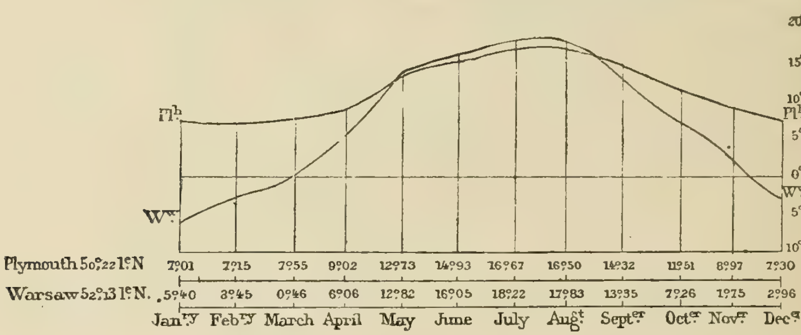


France and England by the accompanying figure; while occasionally the north-east winds raise the summer temperature of Paris, and depress that of winter almost to freezing-point; the winds from the south-west equalise the climate, bringing freshness during the warm season and heat during the cold.

Another great climatic contrast is that presented by the sea-shore, and the regions situated in the interior of continents under the same latitude. In consequence of the incessant mingling of its waters, the sea equalizes temperatures; into the polar regions it pours the warm waters from the equator, under the tropics it receives the afflux of the polar currents, the revolution of its waves bringing coolness to the burning zones, and carrying warmth to the region of snows. Owing to its mobility the sea has, so to speak, no degrees of latitude; it mixes climates, diminishes the extremes of heat and cold on the shores which it bathes, maintains in the march of the seasons a pace much more gently graduated than it is in countries remote from the ocean. To countries which would be subject to polar cold if they were not situated on the border of the waves, the sea imparts the warmth of the temperate zone; it prolongs spring into summer, and autumn into winter. The intense cold and overwhelming heat to which one is subjected in the interior

of continents are completely unknown in the open sea; no traveller has yet observed any oceanic temperature above 88 degrees. We may judge of the moderating influence of the sea by the comparison of two cities situated nearly in the same latitude, one in the interior of the continent, and the other on the shores of the ocean, such as Plymouth, bathed by the mild vapours of the Channel, and Warsaw, placed nearly in the centre of the continent of Europe. M. Emmanuel Liais, who has deeply studied this question, has taken as an example two places much nearer to one another—Paris and Cherbourg. Though this latter town is nearly one degree of latitude more to the north than Paris, its mean temperature is notwithstanding higher; it is 52·3 degrees, that of Paris being only 51·3 degrees. The difference is much greater between the winter climates of the two cities, for during a series of nine years the mean temperature of the three winter months was 44 degrees at Cherbourg, and 38 degrees at Paris. The contrast between the winter temperature of the two localities is all the stronger the intenser the cold at Paris, for it is precisely then that the relatively warm waters of the sea exercise their greatest influence in softening the climate on the coast. On the other hand, the sea lowers the temperature of Cherbourg, for in summer the warmest month is cooler by 2·6 degrees than Paris. In short, the six months from October to March

Fig. 154.—Continental Climate of Warsaw, and Oceanic Climate of Plymouth.



are warmer, while the six months from April to September are cooler. The greatest difference between the highest and lowest annual temperature was 78 degrees at Paris during the four years which elapsed from 1848 to 1852; at Cherbourg it was only 66 degrees during the same period. This difference between the climates of the coasts of Cotentin and the valley of the Seine produces a corresponding difference between the vegetation of the two districts. In the environs of Cherbourg fig-trees, laurels, myrtles, and a great many other species of trees and shrubs, which would perish in the neighbourhood of Paris, are very luxuriant. It is the same on all the coasts of Brittany, and especially at Roscoff, where an enormous fig-tree is to be seen, one of the most magnificent of the wonders of the vegetable world.

The contrast is greater still between islands surrounded by a comparatively warm sea, like Ireland and Great Britain, and the regions entirely continental, situated, like the steppes of Tartary or the plateaux of Central Asia, at more than 600 miles from the shores of the ocean. While in Ireland, which is bathed by the waters of the Gulf-stream, a temperature comparatively cool in summer and warm in winter preserves a constant vegetation, transforming it into the "emerald isle of the seas," the steppes of the Bashkirs, lying under the same latitude, are

by turns burnt up by the heat and frozen by the cold; and all vegetation there is impoverished. In the environs of Astrakhan, which is at the same distance from the equator as the vineyards of the Charente, the grapes yield excellent wine, owing to the great heat of summer, but have to be buried in winter to escape the fatal action of the cold.

The other climatic contrasts observed in different countries at the same latitude result from the variety of surface and soil. High mountains change the normal temperature of a country either by arresting or turning aside warm or cold winds, or by lowering the temperature of the atmosphere and depriving it of the moisture which it contained. Forests have also their action. They shelter the ground against the rays of the sun, and when the heat received by the earth returns into space, their interlacing branches are an immense obstacle to radiation. The general influence which they exercise on climate is moderating, just as that of the sea: they assimilate extremes by cooling the summer and warming the winter, in the same way that a moist and marshy soil receives heat more slowly than arid lands or sandy tracts, but also retains it with more tenacity. Each exterior feature of the planet modifies the local climate and distinguishes it from that of every surrounding district in its diurnal, monthly, annual, and secular oscillations.

CHAPTER XLIX.

ISOTHERMAL LINES.—THERMAL EQUATOR.—POLES OF COLD.—INCREASE OF TEMPERATURE TOWARDS THE POLES.—OPEN SEAS.

FIFTY years ago Humboldt first conceived the idea of uniting by lines all parts of the earth having the same annual average temperature. These imaginary lines, traced on the circumference of the globe, are called *isothermals;* they give the thermal latitude, which differs widely from the geometrical latitude. While the lines of degrees traced every 69½ miles parallel to the equator are of a perfect regularity, and correspond to other imaginary lines traced by astronomers on the skies, the isothermals are contorted in numerous sinuosities of different forms in all parts of the earth. The various causes which modify the temperature of a place, and consequently curve the isothermal lines towards the pole or the equator, have been enumerated with the greatest care by Humboldt. Next to latitude, the principal causes known are the direction of the atmospheric and marine currents, the elevation above the sea-level, the arrangement of mountain-chains, the outline of the coasts, their relation to the neighbouring seas, the nature of the soil and vegetation.

The thermal equator, that is to say, the curve of the greatest average heat on each side of which the temperature gradually diminishes towards the poles, lies almost entirely in the northern hemisphere, which is warmer than the southern. According to the observations of meteorologists, this line traverses America near the isthmus of Panama, at the point of junction of the two continents, then runs along the coasts of Columbia, Venezuela, and Guiana, to the embouchure of the Amazons, and there bends slightly to the south of the equator. Over the Atlantic the curve of the greatest heat ascends obliquely towards the African continent and the Sahara, the hottest region of the whole world. The precise direction taken by the thermal equator is not yet known either in this burning country or in the Arabian desert, or over the coast of the Indian peninsula: it is only certain that in traversing the Old World it continues to keep north of the equinoctial line. In the sea of Sunda and the Pacific Ocean it bends again to the south, and perhaps penetrates into the southern hemisphere at various points. Seeing the want of continuous thermometrical observations over a long period of time, the thermal equator can only as yet be traced on the maps in a provisional manner: it is simply an approximation that subsequent researches will bring nearer and nearer to the truth.

Over various points of this line of greatest heat the temperature is far from being the same everywhere. Above the ocean it is from 77 degrees to 79 degrees;

ISOTHERM


ASIA
Behring's Straits
NORTH AMERICA
Greenland
Baffins Bay
Bay of Hudson
Iceland
Newfoundland
New York
San Francisco
Antilles
Caracas
PACIFIC
Thermal Equator in Summer
Thermal Equator
Equator
SOUTH AMERICA
Rio Janeiro
Buenos Ayres
Cape Horn
Australia
Sydney
New Zealand
Antarctic Polar Circle
Isothermals of the Year
Summer Isothermals.

L LINES. PL. XIX.

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on the coasts of Columbia and Guiana it is 81 degrees on an average; at Calcutta it attains 82·5 degrees; at the mouths of the Niger it is much greater (85·3 degrees); and undoubtedly in many parts of the interior of Africa and Arabia never reached by refreshing breezes from the sea, the mean temperature of the year is still higher. Thus the tracts where this exceptional heat prevails form on the course of the thermal equator a sort of island, the outlines of which wander according to the differences of relief on the surface and the atmospheric phenomena. The researches of Mahlmann have proved that islands of less heat exist in the tropical zone, and that the thermal equator sometimes bifurcates and encloses colder regions.

The sinuosities of the isothermals properly so called are caused over all the terrestrial circumference by these isothermal islands of a higher or lower temperature. In the southern hemisphere, where the continents are diminished gradually towards the south, and where the moderating influence of the ocean tends to eliminate all climatic differences, the lines of equal annual temperature seem to be pretty regular, and in the Antarctic Ocean they may be considered parallel to the degrees of latitude. The most marked curves of these isothermals of the south are those which are developed immediately to the West of Africa and South America under the influence of the currents of cold water which flow towards the equator along the coasts of these two continents.

In the northern hemisphere the sinuosities of the isothermal lines are much more marked than those in the southern, and cut the degrees of latitude at all angles. Considered in a general manner, the isothermal lines of the northern hemisphere have the form of a double wave, the crests of which rise above the western shores of Europe, and towards those of California, while the depressions coincide with the eastern coasts of the Old and New World. The highest isothermal wave is that which rises off the coasts of New England, Newfoundland, and Ireland, the culminating point of which is found to the north of the British Islands; one would say that it was traced over the Gulf-stream, and in fact it is this current of warm water which drives the whole system of isotherms towards the north. The line of 59° F., which passes over the coast of North Carolina, near Cape Hatteras, cuts the south of France from Bayonne to Montpellier at 9 degrees latitude farther to the north. Between New York and Dublin, where the mean temperature is the same (50 degrees), the difference of latitude is 13 degrees; it is 16 degrees, or nearly 1100 miles, between Quebec and Trondhjem, where the isotherm of 39·2 degrees passes. And the difference is still greater for the line of freezing-point.

Whatever may be the sinuosities of the lines of equal temperature, they all indicate a more or less rapid decrease of heat between the equator and the two polar zones. In the northern hemisphere it has been possible to trace approximately the various isothermal lines as far as that which gives an average temperature of 5 degrees, but beyond this observations have been too rare for it to be possible to mark lines, the course of which is not almost entirely hypothetical; the general direction, however, of the curves renders it very probable that in the polar circle there exist at least two isothermal islands of cold corresponding to the two isothermal islands of heat which are found in the neighbourhood of the equator. According to Brewster, there are in the Frozen Ocean of the north two of these regions of greatest cold, real meteorological poles moving incessantly according to the alternations of the seasons, but in all their oscillations keeping themselves at several hundred miles distant from the geometrical pole. One of these poles of cold is found to the north of the Asiatic continent, not far from the archipelago known under the name of New Siberia, and its average temperature is about

1·5 degrees. The American pole oscillates in the midst of the western islands of the polar archipelago, and the average there is more than 2 degrees below zero. The researches of Mühry have rendered it very probable that in the Antarctic hemisphere there also exist two poles of cold. The regions whose climate is most severe would thus be situated under latitudes which man has already visited, and consequently the poles, properly so called, would not be that formidable citadel of ice that geographers once imagined. It is erroneous to believe in the existence of an ice-field all round the pole gradually thickening towards the centre; and erroneous to picture to oneself the two extremities of the terrestrial axis as for ever inapproachable, because of the intensity of the cold.

Besides, the calculations of the mathematician Plana tend to make us believe that the total quantity of heat received increases gradually from the polar circle to the central depression of the Arctic zone. According to the researches made a long time since by the mathematician Lambert, it was thought that the total solar heat at the equator being taken as 700, it would be no more than 646 at the tropic of Cancer, 516 at the 45th degree of latitude, 350 at the Arctic circle, and that at the pole itself it would be represented by the much lower number of 287. In consequence of elements neglected in these calculations, it is found, on the contrary, that the mean temperature, after having gradually decreased from the tropics to the limits of the glacial zone, afterwards rises in a normal manner as far as the pole, which would thus be, at least theoretically, the warmest point of all the polar region, the cold being less severe at the North Pole than it is on the coast of North America and Siberia at 1600 miles farther to the south. However it may be, it is certain that during the six months of summer the solar heat is greater at the pole than at any other part of the Arctic zone, for, according to the expression of M. Gustave Lambert, "it is always noon" during the summer of the pole because of the position of the earth relatively to the sun. According to calculations made by Halley, nearly two centuries ago, the summer mean must increase from the 60th degree of latitude to the North Pole in the proportion of 9 to 10.

The experience of polar navigators has fully confirmed the results of the theory, according to which the series of Arctic isothermals would mark a gradual increase of temperature. On his celebrated voyage of 1827, Parry ventured with his bold companions on the great ice-field, which extended to the north of Spitzbergen. Imagining that this field was a real continent of ice, he hastened to cross these polar regions as if they were the frozen steppes of Siberia; but as the sledges advanced towards the north, the ice-field became lighter and more fissured. It was floating to the south, carried along by a drifting current, and before the travellers, on the side next the pole they so much desired to approach, stretched an open sea where floated only a few scattered pieces of ice. At the extreme point of his perilous expedition towards the north, Kane also discovered an immense sheet of water completely free from ice, and that immediately to the north of Smith's Sound, where the mingled fragments of glaciers and ice-fields form a labyrinth difficult to traverse. To the north of the coasts of Siberia, all encumbered with "toroses," Wrangell and other navigators have also ascertained the existence of an open sea, to which they have given the name of Polynia. Finally, in the Antarctic hemisphere, Sir James Ross found tracts relatively free from ice beyond that high wall through which he had to make his way with so much difficulty. Thus it may be admitted as probable that there does not exist a region of unbroken ice at the two extremities of the earth, but rather an open sea with a relatively elevated temperature, and surrounded on all sides either by islands and

archipelagoes, or by a circular ice-field. The two girdles of northern and southern ice would be, as M. Charles Grad says, the visible representation of the isothermal lines of the lowest temperature, and on each side the severity of the cold would diminish. Nevertheless Nordenskjöld, who in 1868 came within 480 miles of the pole, has no faith in the existence of an open Arctic sea. Weyprecht attributes the open waters of the Frozen Ocean to the shifting of the ice-fields, which drift from Greenland to Siberia or in the opposite directions, according to the oscillations of the temperature and the marine currents.

CHAPTER L.

EXTREMES OF TEMPERATURE.—ISOCHIMENAL AND ISOTHERAL LINES.—DAILY AND MONTHLY VARIATIONS.—DECREASE OF WARMTH IN THE UPPER STRATA OF THE AIR.—VARIATIONS OF CLIMATE DURING THE HISTORICAL AND GEOLOGICAL PERIODS.

THE total difference observed on various points of the earth between the highest and lowest extremes of temperature much exceeds 200 degrees. Captain Back endured at Fort Reliance, in British America, 70 degrees below zero, which is hardly inferior to that which is believed to prevail in the interplanetary spaces; a Russian traveller observed near Semipalatinsk 72 degrees; still more, Gmelin is said to have experienced (?) at Kiringa, in Siberia, the truly terrible cold of 121 degrees below zero; while M. Duveyrier, travelling in the country of the Touaregs, saw the thermometric column indicate a warmth of 155·5 degrees. Thus, without taking into account the observation probably erroneous, the series of ascertained temperatures includes from 250 degrees to 260 degrees, and man has frequently to endure extremes of cold and warmth without being able to measure them still greater than those which have been regularly observed. Even on one point of the earth the highest and lowest temperatures in the course of the year often present the enormous difference of more than 144 degrees. In the vast frozen plains of North America, where Back endured the severe cold of 70 degrees below zero, Franklin experienced during the long summer day a torrid heat of 87 degrees. Between these extremes the scale of temperature traversed in the year is about 157 degrees. Not far from the equator, the so-called "burning" regions of the Sahara present, according to Duveyrier, a thermometrical difference almost as considerable as that of the polar countries of British America. This is because, in spite of the difference of latitude, the deserts of Africa and the granitic plains of North America resemble each other by their continental position, and the relative uniformity of their relief. Remote from the ocean, that great equalizer of climate, and destitute of high mountain-chains, which could arrest the cold or warm winds blowing from different points of the horizon, these countries must be subject to very abrupt alternations of temperature. How much more equable are climates where the moderating action of marine waters—as at Surinam, the Canaries, and Madeira—or else the shelter offered by a rampart of mountains, as on the coast of the Genoese Alps, maintaining a temperature whose extremes only differ from 20 degrees to 25 degrees. In France, a country which represents a fair average through many of its physical features, the difference between the intensest cold and greatest heat rarely reaches 99 degrees, and in ordinary years does not exceed 81 degrees. During all the series of meteorological

observations made at Paris during the last century, the mercury has oscillated in all 110·5 degrees; at Nice the greatest variation has been 78 degrees.

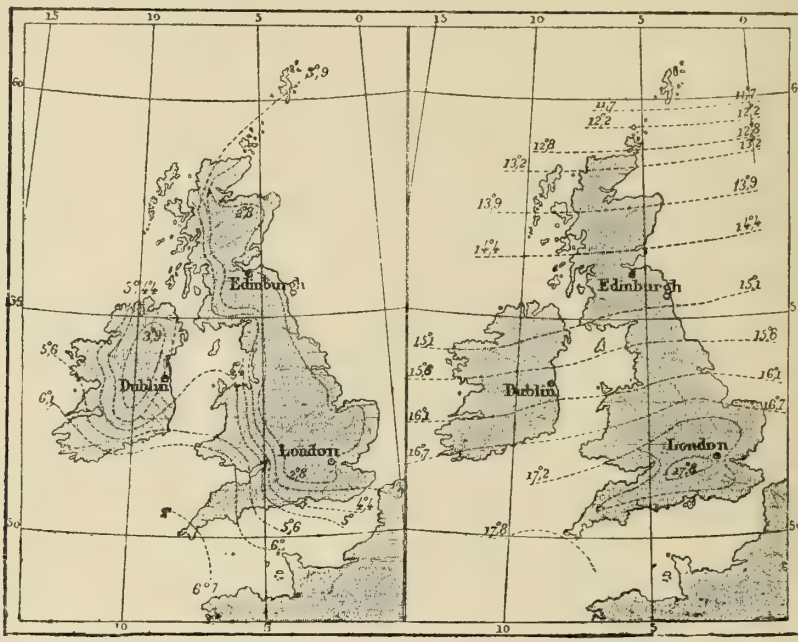
Through this greater or less change in the height of the thermometer in various countries of the world, it results that the lines of equal temperature for each season, and more still for each month, are much more sinuous than the isothermals of the year. The name of *isochimenal* lines is given to those which unite all the localities where the winter temperature oscillates to about the same extent; the *isotheral* lines are the curves drawn through those places which present on an average the same summer temperature. We can also cover maps with *isoeral* lines, or equal temperature in spring, and *isometoporal* lines, or equal temperature in autumn; and *isomenal* lines, or curves of average heat for each month in the year, might even be drawn across the continents and seas. But meteorological observations not being yet numerous enough for this immense labour to offer all the certainty desired, it is better to limit oneself provisionally to the study of isotheral and isochimenal lines, which have, above all other lines of seasonal or monthly temperature, the advantage of indicating the extreme periods in the alternations of heat.

The direction followed by the isotheral and isochimenal lines in Europe and North America is a singularly striking example of the influence which the unequal distribution of land and sea exercises on climate. In summer, when the northern hemisphere is inclined towards the sun, and receives the greatest quantity of heat, the countries situated in the interior of the continents of the north are much more heated than those bordering on the sea. During the cold season the contrary takes place: the winds and the currents coming from the equatorial zone temper the severity of the cold in the neighbourhood of the coasts, while far into the continents the tempering influence of the ocean and the aërial currents of the south make themselves much less felt. Consequently the isotheral lines curve towards the north in the two northern masses of the Old and New World, and bend to the south in traversing the Atlantic and the Pacific; on the other hand, the isochimenal lines bend to the south in their passage across the continents of America, Europe, and Asia, and curve in certain places by more than 600 miles to the north in crossing the sea. The contrasts between the curves of the continental climate and those of the oceanic become still more striking when we take, in order to oppose them to one another, as Kiepert did, the isothermal lines of January, which is on an average the coldest month, and those of July, which is the warmest. In Great Britain especially, this opposition of winter and summer climates is remarkable. The mild influence of the Gulf-stream and the west winds goes even so far (as is shown by one half of Fig. 155) as completely to lead back the isochimenal lines, which are thus developed from the south to north, instead of running from west to east, parallel to the degrees of latitude.

We can understand the decided influence which these inequalities, with their alternations of warmth in countries having in other respects the same mean temperature, must exercise on plants and animals. One kind, which can well support the severity of winter without dreading the heat of summer, is propagated over vast regions in the interior of continents; another kind, which shrinks from the low winter temperatures, when remote from the sea-shore, does not pass latitudes which it crosses by several degrees in the neighbourhood of the ocean. Thus the elk lives in the peninsula of Scandinavia, which is bathed by the tepid waters of the Gulf-stream, at 700 miles farther north than in Siberia, with its extremes of heat and cold.

The course of the various isothermal lines depends in great part simply on probabilities, since between all the points whose temperature has been observed during a longer or shorter period of years, or only months, there remain here and there wide intervals where no thermometrical notes have yet been made. There are uncertain spaces through which meteorologists cannot drawn lines of equal temperature, inasmuch as they have no series of precise observations on which to base them. Thousands of persons in the United States, Canada, the Antilles, Hindostan, and South Africa, have joined their efforts to those of all the official savants to note down the innumerable oscillations of heat and cold, which by their grouping may reveal the laws of temperature. Day after day they ascertain the horary variations which afterwards allow them to establish the mean heat of the day, month, and year, and then to compare the place whose condition they have

Fig. 155.—Climates of the British Isles.

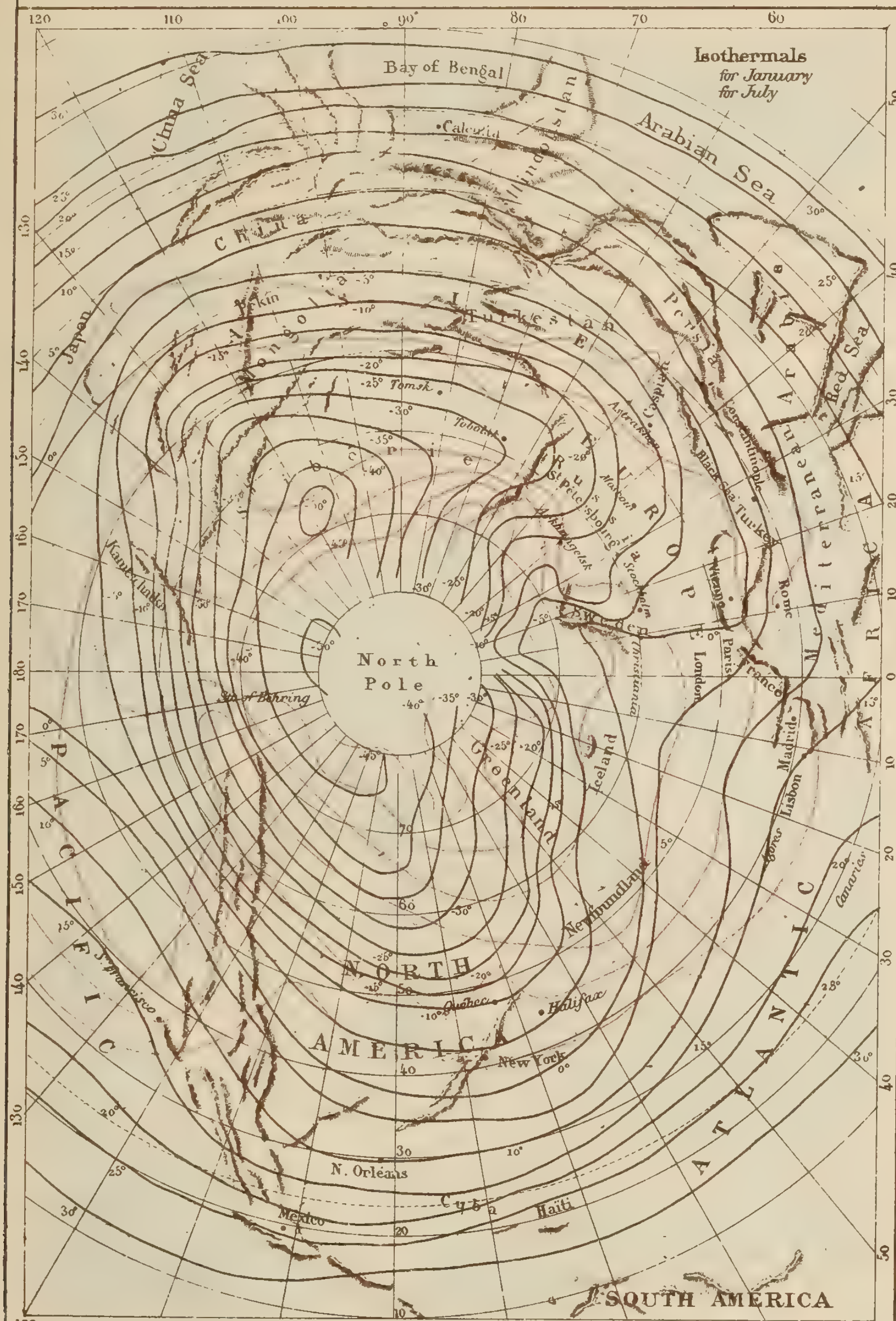


Isochimenal Lines. Isotheral Lines.

studied with other localities where the alternations of heat and cold succeed each other in a more or less analogous manner.

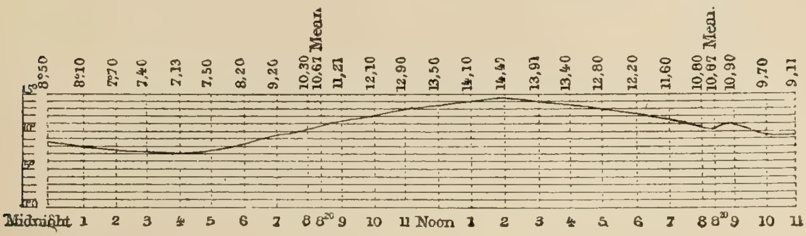
From millions of hourly variations which have been observed for a century in various parts of the world, it results that the greatest heat of the day makes itself felt, on an average, between one and two o'clock in the afternoon, while the lowest temperature precedes sunrise by an hour, or even half an hour. It is easy to understand why the extremes of heat and cold do not coincide exactly with midday and midnight. After midday hour, when the sun again begins to incline towards the horizon, its rays continue to heat the ground and the atmosphere; it is only later that the loss of warmth caused by radiation equals, and then exceeds, what is gained, and the temperature begins to sink. During the night the contrary phenomena occur; the earth and the atmosphere which surrounds it grow colder till dawn announces the near appearance of the sun, and the nocturnal radiation is compensated for by the increasing heat of the new day. In the island of Java the

ISOTHERMAL LINES FOR JANUARY AND JULY IN THE NORTHERN HEMISPHERE.



diurnal heat attains its maximum a few minutes after one o'clock in the afternoon, and is, on an average, found at its minimum a little before six o'clock in the morning. At Paris, according to the observations of Bouvard, the highest temperature (58°) makes itself felt at two o'clock in the afternoon, the lowest (45°) falls at four o'clock in the morning, and the mean heat of the day, which is at the same time

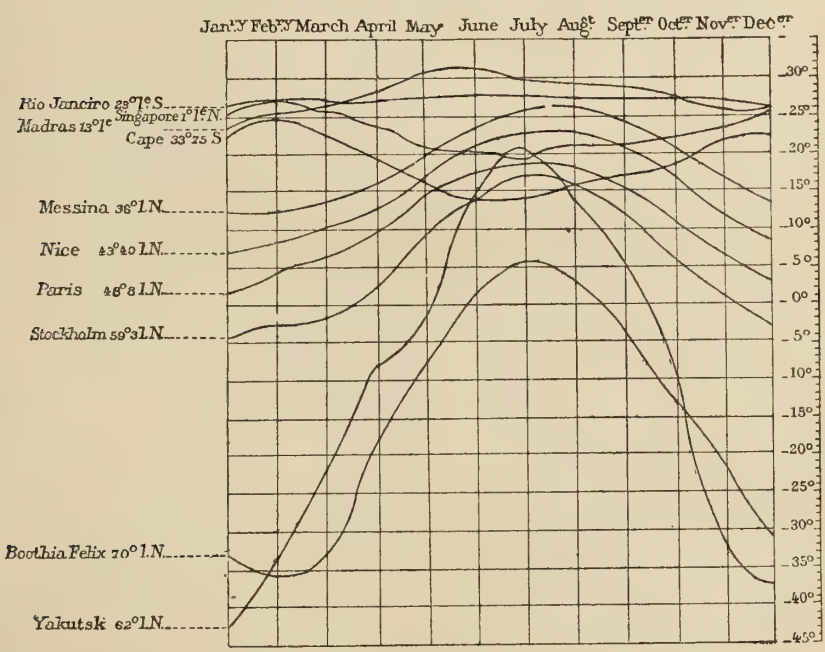
Fig. 156.—Diurnal Variations in the mean Temperature at Paris.



that of the year (51·2°), returns at the corresponding periods of 8·20 in the morning and the same hour in the evening.

The monthly variations present in their regular oscillations the same phenomena as the hourly ones. It is not at the solstice of June that the northern hemisphere enjoys the greatest quantity of heat, and it is not at the solstice of December that it is subject to the severest cold. After the sun has ceased to illuminate from the

Fig. 157.—Monthly Variations of the Temperature in Various Places.



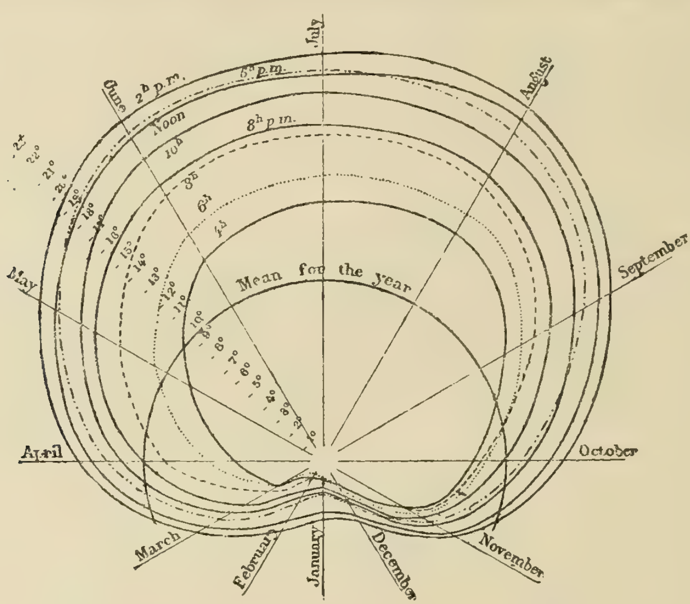
zenith countries situated beneath the tropic of Cancer, the heat still augments till July and even till August in a great many regions situated towards the North Pole, and in mountainous countries. On the other hand, the greatest cold of the northern hemisphere continues and is even aggravated when the solar rays already bring an increasing quantity of heat. In Europe and North America it is the

month of January that is ordinarily the coldest; and there are even some towns, like Palermo, Gibraltar, and New Orleans, where the lowest temperature of the year falls in February, hardly a month before the vernal equinox.

From the observations made at Greenwich during the last half-century, it appears that January 8th is the coldest and July 14th or 15th the hottest day of the average year; while April 27th and October 20th correspond to the mean annual temperature.

In the neighbourhood of the equator, illuminated by a vertical sun, the monthly variations of temperature are much less important than in countries situated beyond the tropics, and they depend much more on the direction of the winds and the alternation of rains and droughts, than on the position of the sun in the ecliptic. Thus at Singapore the total difference between the coldest and hottest month is scarcely 3·5 degrees. To the south of the equinoctial line the monthly variations become more and more considerable, but in the reverse order to that ascertained in

Fig. 158.—Temperatures of the same hours in different Months, at Brussels (after Quetelet).



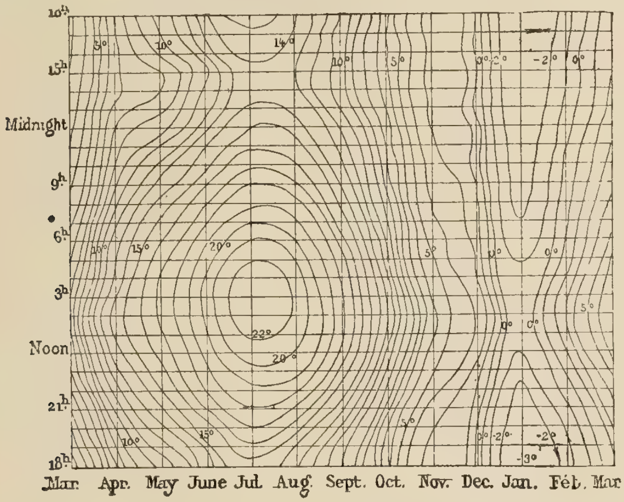
the northern hemisphere. It results from the researches of Dove that, taking the average of all the temperatures over the whole world, the month of July is the hottest of all the year.

In order to account for the average variation of cold and heat from month to month, and at different hours of the day, meteorologists have had the ingenious notion of drawing curves which, by their deviation from the central point, taken as zero, indicate the hourly temperature for every month of the year. We give as an example of these diagrams a figure which enables one to read the temperature of various hours at Brussels during all the cycle of a year. Another very elegant figure (Fig. 159) drawn by M. Leon Salanne, after the data of Kämtz, represents the thermometrical curves at all hours of the day according to the month; it is the meeting-point of the horizontal and vertical lines which indicates the degree of heat. Thus, as is seen by figure 160, constructed with the same elements, the difference of temperature between day and night is much greater in summer than

in winter. Besides, the curves show clearly that the long summer is followed by a short one called "St. Martin's summer," and that a return of cold is generally felt in May.

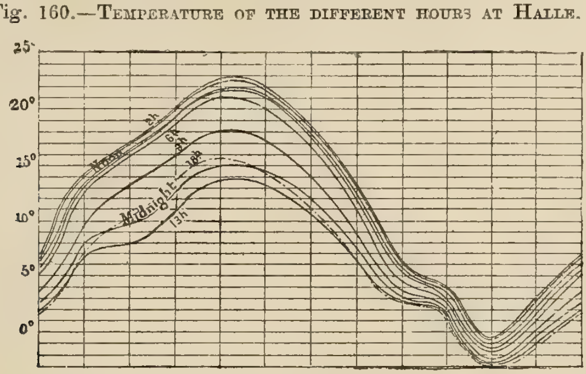
Above the surface of the ground meteorologists observe in the atmospheric strata a decrease of temperature similar to that which takes place between the torrid and the frigid zone. The rarefied air of the upper regions must necessarily be chilled

Fig. 159.—Variation of the Mean Monthly Temperature, in the same hours, at Halle.



the nearer it approaches to the cold interplanetary spaces, and loses the watery vapour which serves as a screen for the nocturnal radiation of heat. Nevertheless, it is seldom that the temperature falls in a perfectly regular manner from the surface of the ground and the ocean to the heights of the atmosphere, for winds, clouds, and other meteoric phenomena incessantly modify the condition of the aërial

Fig. 160.—Temperature of the different hours at Halle.

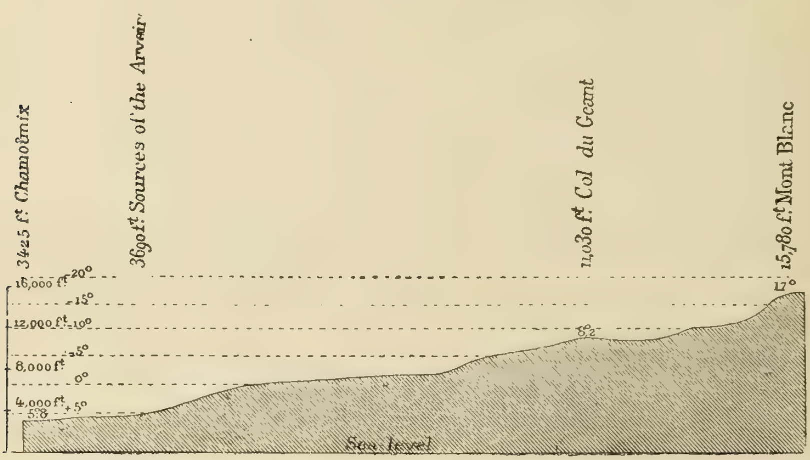


strata, and frequently those which rise on the sides of a mountain penetrate from a relatively cold zone to a more elevated temperature. The order of the climates is found reversed. Thus in the winter from 1838-1839 the cold was 4° below zero at Andancette, on the banks of the Rhone, while in the mountains of St. Agrève, at 3690 feet higher, it was 10·4 above zero. In the same way Mr. Glaisher ascertained in the night of October 2nd, 1867, a continuous increase of warmth to the

height of 948 feet. In other ascents the same aeronaut had found no appreciable change between the temperature of the ground and that of the atmosphere to the height of 2300 feet. Besides, M. Prestel has proved, by long and precise observations, that in that portion of the air which rests immediately on the ground the heat increases constantly from below, to at least 30 feet. In consequence of meteorological preturbations this zone of increasing temperature may sometimes rise to a considerable height above the surface.

Unfortunately, the series of regular observations made at a great height are still very rare; and even in Switzerland, where so many eminent men busy themselves in scientific researches, there only exist two points above 2000 feet, the hospice of St. Bernard and the pass of St. Gothard, where the monthly averages of temperature are ascertained with certainty. It is therefore only in an approximate manner that we have been able to calculate the laws according to which the heat diminishes in the higher strata of the air during the various seasons. At all events, it is certain that during the summer and in full sunlight, the aërial strata of different temperature are much thinner in proportion than in winter and during the night.

Fig. 161.—Succession of Climates on the Slopes of Mont Blanc.



It may be said in a general way, with Helmholz, that on the sides of the Swiss mountains the heat diminishes upwards by one degree at intervals of 300 feet in summer and 450 feet in winter; according to M. Charles Martius, the average intervals for the entire year would be from 312 to 315 feet. Other savants have found slightly different figures. Thus de Saussure, to whom the honour belongs of having first made observations of this kind, ascertained that on the western slopes of Mont Blanc the decrease of temperature during the warm season was about one degree for 300 feet. However, each mountain differs in this respect, and on isolated peaks like Le Ventoux the superimposed climates are much closer to each other than on the sides of heights which form part of vast mountain systems. A comparative study of temperatures shows that it is much colder on the plains of the polar regions than on the uplands of Central Europe. Thus the glass falls considerably lower at St. Petersburg than on the Col du Géant, and at Yakutsk than on Mont Blanc.

Studer estimates the average height of the isothermal line of 50 degrees in the Alpine masses at 1300 feet high; the line of 41 degrees would rest at 4200

feet above the sea-level; that of 32 degrees would surround the mountains at 7200 feet, and the temperature would continue thus to diminish one degree for every 300 feet to the summits. Thus in the maps which represent the relief of the mountains by concentric curves of level, these curves may serve to illustrate not only the increase of altitude, but at the same time the fall of the average temperature; they are like superimposed degrees of latitude. Further, the observations of aeronauts have rendered it probable that in the upper regions of the atmosphere the interval increases more and more for every decrease of one degree in temperature. Beyond the limits of the atmosphere all the heat which the rays of the sun impart to the earth disappears in the cold of space, which is estimated at about 108 degrees below the freezing point, and reigns supreme throughout interstellar space.

The study of the climates which now prevail on the surface of the globe ought to be completed by that of the changes experienced during historical times; unfortunately, the earliest meteorological observations date from an epoch so recent that the too scanty and very uncertain facts on which we have to depend to arrive at a knowledge of the condition of the temperature in former centuries, do not authorize us to establish a precise law of the modification of climates. Long ago Arago attempted to establish, by very ingenious considerations, that in the space of the last thirty centuries Palestine has continually enjoyed a temperature from 70 to 71 degrees; for now, as in the times of Jewish history, the northern limit of the zone is where dates ripen and the southern limit of the vine coincide, the banks of the Jordan. Nevertheless, Arago did not refuse to believe that in western Europe the laws regulating the temperature have notably altered; this is proved, he says, by the gradual retrogradation of the vineyards towards the south. In our days the vine is no longer cultivated on the shores of the Bristol Channel, nor in Flanders, nor in Brittany; and in these countries, which the chroniclers—perhaps too laudatory—tell us produced exquisite wines, grapes cannot ripen now save in exceptional years. Mr. Fuster says that titles of property going back as far as 1561 state, that formerly the vintage took place at heights of 2000 feet on the sides of the mountains of Vivarais, where in the present century the vine no longer bears fruit. In the same way, in the environs of Carcassonne the culture of the olive-tree has retrograded from 9 to 10 miles to the south in a hundred years; the sugar-cane has disappeared from Provence, where it was acclimatised; the orange-trees of Hyères, the cultivation of which extended in the sixteenth century as far as the village of Cuers, have been struck with disease under a sky that is no longer favourable to them, and have been obliged to be replaced by trees with less delicate fruit, such as peach or almond-trees. Ought we to see, with M. Alphonse de Candolle, in this gradual retreat of the vines, olives, and orange-trees, only a simple economical fact resulting from the greater facilities for commerce, or is it indeed allowable to infer from these facts that the annual temperature, or at least the summer heat, has diminished in France since the Middle Ages? It seems impossible to reply with certainty. In Scotland, however, horticulture has receded considerably southwards, and even in the woods the hazel holds its ground with difficulty.

It is known also that in many parts of the Alps tradition speaks of a continuous refrigeration of the mountains. According to all the botanists who have travelled in the Alps of Savoy and Switzerland, and the Carpathians, the limits of the high pine forests have sunk sensibly on the slopes of the mountains. M. Kerner estimates the retreat of the forest vegetation at over 300 feet in vertical elevation during the last two or three centuries: everywhere are perceived, beyond the present limits of the greater vegetation, the remains of dried-up trunks and half-

decayed fragments of immense roots. Perhaps man himself, with the animals which accompany him to the high pasture grounds—cows, sheep, and especially goats—is the true author of this gradual decline of the limit of trees. In the course of centuries the forest has little by little ascended the escarpments and the slopes, the higher trees protecting the smaller ones from the cold with their branches; but if the least attack be made on this battle-front either by the axe of man or by the teeth of animals, wind, snow, and avalanches instantly profit by the gap, and the forest begins to descend on the slopes of the mountains. Some botanists attribute this retreat of the pine forests not to the diminution of the annual heat, but to the great inequality of the temperature, to the more sudden alternations of cold and heat, to the frosts and thaws of the spring. What renders this hypothesis very probable is, that in the plains of Hungary constant encroachments of the plants of the steppes have been observed in a westerly direction, and yet no movement in the contrary way has been remarked of western species. It is concluded from this that the excessive climates advance gradually towards the west.

Besides this, direct thermometric observations have proved that for a century the cold has slightly increased at various places in Germany; at Ratisbon, Prague, Hamburg, and Arnstadt the month of December having become relatively much colder, while January has become notably warmer. On the other hand, Glaisher has ascertained that the mean temperature of England has increased by 2 degrees in the last hundred years, and for the single month of January the increase of temperature is no less than 3 degrees. It should, however, be remembered that a hundred years ago the Greenwich Observatory stood in the open country, whereas now it is wrapped in the smoke and fogs of the great metropolis. The local conditions have thus completely changed. But in France the extremes have certainly drawn nearer to each other, the climate having become milder and more equable.

Another climatic change seems likewise to be proved: Iceland and eastern Greenland have become much colder since the fourteenth century, for in the first-named country the large trees have ceased to grow, and on the opposite shores of Greenland a number of valleys, formerly inhabited, have become completely inaccessible in consequence of being invaded by ice. However it may be, we cannot doubt that climates are incessantly modified in a more or less sensible manner over all points of the terrestrial surface, since the physical phenomena, from which the unequal distribution of temperature in part depend, are themselves incessantly changing. The mountains, the mass of which arrests the winds, contribute to the formation of clouds, and attract snow and rain; further, they are lowered little by little by denudation, and their materials serve to fill up the lakes, and to throw long peninsulas out into the sea; rivers change their course, and their volume of water increases or diminishes; marshes are dried up, while others are formed in the midst of plains; continents sink or rise; here archipelagoes show themselves above the ocean, elsewhere islands are swallowed up; maritime currents and the winds are in a perpetual change. As the fossil remains of earlier faunas and floras attest, strong climatic oscillations have taken place at each period in the history of the earth, and cycles of heat and cold analogous to our annual seasons of winter and summer have succeeded each other in the course of ages. Without it being necessary to admit a change of axis and variation of terrestrial latitude, we may affirm that the present epoch, like the past, also presents in its climates a whole series of successive changes, and even history proves that the labours of mankind have a very large share in these very important modifications of the condition of our globe.

But when the question is viewed from a broader and more comprehensive standpoint, the conclusion seems inevitable that, during the course of geological time, climatic conditions have gradually become profoundly altered. It is indeed self-evident that, since the first appearance of life in the Eocene epoch, the temperature of the earth has steadily fallen. And, going still farther back, we find that the whole history of the globe, after its separation from the sun, may be regarded as a continual cooling process. There was a time when our planet was too hot for the existence of organised beings, and when it cooled down sufficiently for the development of life, the germs of plants and animals must have been evolved first in the coldest regions, that is, about the two poles. Hence these points are now commonly regarded as the centres of dispersion for living organisms, which spread southwards and northwards in the direction of the equator according as the general temperature became lowered. At last the time came when the poles themselves became too cold any longer to support that life to which they had originally given birth. In the same way the time must also come when the torrid will be transformed to temperate zones, and when the equatorial regions will present the most favourable conditions for the continued evolution of life on the globe. Then will follow the last scene of all, when our planet must share the fate of its satellite, the moon, which owing to its smaller size, has already passed through all these vicissitudes, gradually changing from a state of incandescence to the condition of a frozen lifeless mass. Thus it appears from the cosmic history of the earth that its temperature is everywhere falling, although this cooling process is so slow that it can be clearly detected only by the comparative study of epochs separated one from the other by long intervals of geological time.

The process may even be occasionally retarded or accelerated by cosmical causes, which cannot yet be fully determined. Hence the phenomenon of glaciation in the northern, and, as shown by recent observation, also in the southern hemisphere, by which the present temperate zones were for a time reduced to the conditions of the Arctic and Antarctic circumpolar regions. But these temporary oscillations of the terrestrial temperature, connected with the precession of the equinoxes and with other obscure cosmical causes, are mere disturbing elements that cannot permanently arrest the general cooling process which set in the moment the globe had an independent existence, and which must continue until it has run its natural course.

Part III.—LIFE.

CHAPTER LI.

THE ASSEMBLAGE OF LIVING CREATURES.—NUMBER OF VEGETABLE SPECIES.—PROPORTION OF DICOTYLEDONS, MONOCOTYLEDONS, AND CRYPTOGAMS.—FORESTS AND SAVANNAHS.

FROM the simple harmony of its forms, the regularity of all its external features, the purity of the air which surrounds it, and the light which colours it, the surface of the planet is, as a whole, of magnificent beauty; but that which lends especial grace and charm to the earth is the infinite number of organisms which people it. It is these which add such a marvellous variety of aspect and such great animation to the cold majesty which the bare face of the rocks presents, such as we still see here and there in desert regions destitute of vegetation. Light, heat, electricity, and magnetism, which give rise to so many changing phenomena in the life-history of the globe, develop centres of activity in that world of vegetable and animal life, which the creative force of the elements engenders by a mysterious transformation. Hundreds of millions of different species, composed of innumerable particles, which are continually in a state of transition from the living animal to the earth, and from the earth to the living animal, germinate, grow, and die, to give place in their turn to other numberless generations of organisms. Thus multitudes succeed to multitudes in the immense series of ages. The upper strata of the earth are renewed by all this matter which has lived. The coal-measures, the chalk and the numerous other strata of limestone, which present in many places several miles of thickness, and thus constitute a very important part of the framework of our globe, are nothing else than the remains of plants and animals that formerly inhabited the land and the ocean. In our days, too, new layers, composed entirely of the remains of organized bodies, are constantly being formed, and almost the whole surface of the land is covered with humus or vegetable soil, formed by the destruction of life, which produces life in its turn.

It is chiefly plants which aid the formation of this nutritious earth, and thus prepare, centuries beforehand, the food of generations to come. In looking to the origin of life, we find certain undecided forms termed by Carus "proto-organisms," which seem to partake at the same time of the nature of the animal and the plant; but on developing they soon exhibit, by their structure and mode of life, the kingdom to which they belong. It is the vegetable kingdom in particular that peoples and embellishes our earth, thanks to the abundance of its species, the

richness of its forms and colours, and the vast dimensions of its trees, some of which, like the *Sequoia* and the *Eucalyptus*, rise to more than 300 feet high into the region of the clouds. But how does the planet produce the innumerable living bodies on its surface, from the green conferva, which germinates on ponds, to man, who, proud of his strength, bravely meets his destiny? This is the great problem which excites the attention of the learned, and which is not, perhaps, altogether insoluble. The subject has given rise to much discussion, and to many experiments by chemists and biologists, without at present any definite result being arrived at.

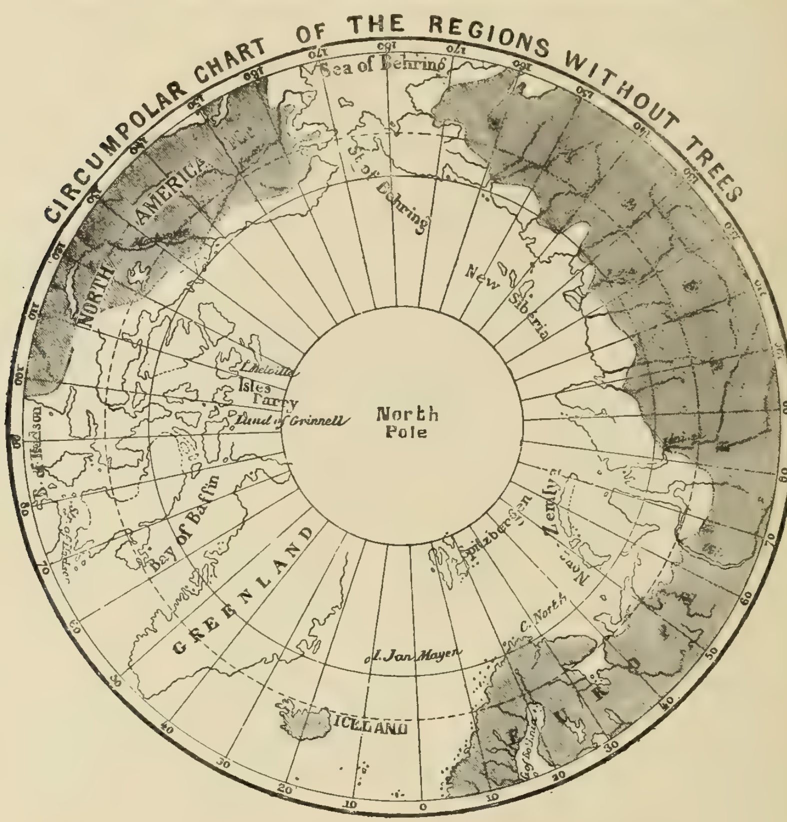
Botanists have not yet had time to count the prodigious number of plants which surround us, from the great oak, with spreading foliage, to the humble lichen spread on the ground like a stain of blood. Besides, if the multitude of the vegetable species have not yet been computed, it must also be said that naturalists are not yet agreed on the definition of species, some seeing simply varieties where others find quite distinct characters. A century ago Linnæus knew only 6000 species; the lists have since gradually increased in proportion as the various regions of the earth have been more and more explored, and now the total number of plants contained in the herbaria is estimated at about 12,000; the increase has thus been, on an average, about a thousand each year. As to the numerous species which botanists have not yet classified, nor even discovered, we can only judge by proportion of the probable figure. It is thus that M. Alphonse de Candolle has been able to fix, in a general manner, the number of 400,000 to 500,000 species (250,000 being phanerogams), for the whole of the terrestrial flora. Up to our days, therefore, hardly a quarter of our riches has been recognized in the great inventory of the vegetable productions of the globe. And not a year passes without important discoveries being made by travellers in different parts of the world. Even the best-known countries of Europe, which botanists have not ceased to explore for a century, present every year new species to fortunate collectors of plants.

Of the number of classified species already so considerable, the greatest part, or about two-thirds, is composed of dicotyledonous phanerogams, that is to say, of plants with visible flowers, and springing from the ground with at least two primordial leaves: these are the highest species of the vegetable series. Of the third which remains in the whole of terrestrial vegetation, about a half consists of monocotyledons, that is to say, of plants which have also apparent flowers, but which spring up with a single seed-leaf; such are palms, grasses, reeds, and sedges. Finally, the last sixth comprehends the acotyledons or cryptogams, that is to say, plants with flowers concealed or non-existent; fungi, mushrooms, mosses, algæ, and other families of plants which germinate without any primordial leaf, and which, in consequence of their rudimentary organization, occupy the lowest place among living beings. However, the proportions between the three great classes of vegetable species vary in the different countries of the world. The great general law recognized by Humboldt, and brought fully to light by M. Alphonse de Candolle, is that the proportion of dicotyledons increases gradually from the poles to the equator, while the monocotyledons and the cryptogams become relatively more numerous on nearing the poles. Thus warmth of climate is favourable to the dicotyledons, but cold moisture is harmful to them, and in all countries where rain is very abundant the proportional number of the monocotyledons is increased.

A question still more important to man is to know what relative extents are occupied on the surface by absolutely barren spaces, herbaceous regions, and forests

of great trees. Districts entirely destitute of plants are very few; deserts and even changing dunes have their special floras, and even the abrupt walls of rocks are covered in many places with an incrustation of lichens. Thus during the rainy season the Black Rocks of Pungo Audongo, in the country of Angola, appear covered with an immense drapery of velvet, which is nothing else than a network of an infinite number of algæ: when the heat comes, these coatings are dried up and peel off, causing the grey and yellowish lines of the rock to reappear. We may therefore consider the earth as practically clothed with plants throughout its extent; but it is most important to know the part of its surface which is shaded by trees. This is an estimation which has not yet been made, although it presents

Fig. 162.—Map showing treeless regions around the North Pole.



the highest interest, from its connection with the study of the variation of climates and the history of humanity. If we assign to all the forests a surface equal to that of a quarter or fifth part of the land, this is only a hazardous approximation. Botanists have confined themselves to tracing on the north of the continents the limits which polar cold fixes for trees. This limit is found in Scandinavia between the 70th and 71st degrees of latitude, which is not passed by the birch-trees; in Siberia the larches, which are the hardiest trees of the country, advance as far as the 68th degree; in North America the fir grows on the banks of the Coppermine River up to the latitudes of 68 and 69 degrees, and in Labrador up to that of 58 degrees. To the south of this frontier of arborescent species no country is absolutely deprived of trees, and even the southern extremities of the conti-

Ocean.

FORESTS OF THE VOSGES.

PL. XXI.

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Kilomètres

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nent which advances in the direction of the antarctic pole have extensive forests. Certain wooded surfaces of uninhabited countries have no less than several hundred thousand square miles in a single stretch. Formerly, too, the greater part of the regions inhabited by civilised men bore vast forests, which the axe and fire have since greatly thinned. Gaul was covered with trees from the ocean to the Mediterranean, and the cultivated lands were simply clearings like those of the American pioneers in the solitudes of Michigan. The Vosges, a chain of French mountains which is still wooded along the greater part of its extent, was a "Black Forest" like the corresponding system which rises on the other side of the valley of the Rhine. In Germany the great Hercynian forest had, according to the testimony of Roman writers, a length of sixty days' march, and now there

Fig. 163.—Forests of Transylvania.

remain only fragments scattered over the sides of the mountains. Scandinavia, Transylvania, Poland, and Russia still present very vast wooded tracts, estimated in some districts at nine-tenths of the surface, the towns and villages occupying mere "clearings." But there too the work of clearing is accomplished with great rapidity. History and personal examination teach us also that in consequence of the diversity of the combined influences of heat and moisture, the contrast between the steppes of grass and the great forests was formerly as great as it is now in Louisiana between the savannahs and "cypress groves," and in the plain of the Amazons between the *llanos* and *selvas.* The vast sea of grass succeeded without transition to the immense forests; the flowery surface of the "Tchornosjoin" extended over half Russia, while the other half was a boundless forest intersected only by lakes and rivers. Nowadays the labour of the agriculturist consists especially in mixing the species of plants, and alternating, often in an ungraceful manner, woods, fields, and meadows.

CHAPTER LII.

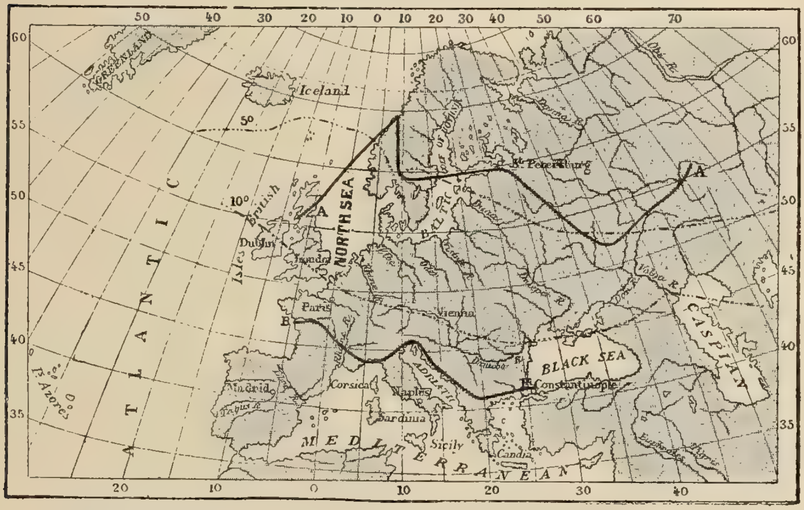
INFLUENCE OF TEMPERATURE, MOISTURE, AND SOLAR RAYS ON VEGETATION.—DISTRIBUTION OF PLANTS.

EACH plant has its special domain, determined not only by the nature of the soil, but also by the various conditions of climate, temperature, light, moisture, the direction and force of winds, and of oceanic currents. During the course of ages the extent of this domain changes incessantly, according to the modifications which are produced in the world of air, and the limits of the region inhabited by the various species are dovetailed into one another in the most complicated manner. The flora indicates the climate; but what is the climate itself in the apparently confused mixture of phenomena which compose it? The preponderating influence is naturally that of temperature; nevertheless we must not think, as most botanists did till very recently, that the limits of the zone of vegetation of each plant are marked on the continents by the sinuosities of the isothermal lines. In fact, as Charles Martins and Alphonse de Candolle remark, each plant requires for its germination and development a certain amount of temperature, differing according to the species. With some, life resumes its activity after the sleep of winter, when the thermometer marks 3 or 5 degrees above the freezing-point; others need a heat of 18, 20, or even 25 and 35 degrees before taking the first step in their career of the year. Each species has, so to say, its particular thermometer, the zero of which corresponds to the degree of temperature when the vegetating force awakens its germs. It is therefore impossible to indicate by general climatic lines the limits of habitation for such or such species, since each one of them has for the commencement of its vital period a different starting-point.

In order to know the heat necessary for plants it would be needful, not to seek for the average result of the alternations of heat and cold during the various seasons, but to estimate the number of hours during which the temperature is maintained above the degree which is for each plant the initial point of its development. It is true that in this estimation the relative number of hours of the day and night are not taken into account, each of which must certainly influence vegetation in a different manner; but such as it is, this calculation is still the truest that it is possible to establish, especially for the annual species which exist only in germs during the winter, and which have not, like trees and perennials, to protect their trunks and branches against the severity of the cold. Thus the climates of London and Odessa, which resemble one another so little in their summers, winters, and extremes of temperature, are nevertheless the same for

vegetable species, whose development commences at 7 or 9 degrees above zero, and which require the same sum-total of heat to arrive at maturity. Even climates so distinct as those of Edinburgh and Moscow, Stockholm and Königsberg, London and Geneva, must produce the same effects on plants which, starting at a certain degree of the thermometer, require the same quantity of heat in a longer or shorter space of time. It results from this, that the areas of habitation of the species have the most various outlines. While on the side of the North Pole the limits of the common columbine (*Aquilegia vulgaris*) and the *Campanula erinus* approach very nearly the course of the isothermal lines of Europe, the frontiers of other zones of plants traverse the continent in all directions, so that it is as impossible to find the least appearance of parallelism in them as in the lines of equal temperature. We may quote, as examples, the curves described by the polar limits of certain well-known trees and shrubs, the holly, the *Chamærops humilis*, the beech, ash, and jasmine. Among the plants of Europe there are even

Fig. 164.—Map showing the Distribution Northwards of Aquilegia vulgaris and Campanula erinus.



A A Polar Limits of Aquilegia vulgaris. ——— Isothermal Lines at 5° and at 10°.
B B „ „ Campanula erinus.

some whose limits indicate an absolute antagonism between the climatic conditions which are necessary to them. Thus the *Dabœcia polifolia*, a delicate plant which fears the cold winters and hot summers, only quits the Azores, with their moist and equable climate, to venture on the Atlantic coasts of Portugal, Spain, France, and Ireland, where rains are abundant and the cold is tempered. The dwarf almond, on the contrary, spreads itself fearlessly from the banks of the Danube to the foot of the Ural mountains across the Russian steppes, where dry and very cold winters succeed to excessive heat.

According to the method of observing temperatures first indicated by Reaumur and subsequently supported by Boussingault, Gasparin, and particularly by Alphonse de Candolle, we are enabled to explain the sinuosities which the limits of vegetable areas present. This method, based on observation, consists in computing the "amount of heat" necessary to the complete development of each plant; that is to say, in calculating daily the degrees of average heat which exceed the temperature

at which the plant has commenced its life for the year, and reckoning up the sum-total of these daily heats. Certain plants belonging to the frigid zone, which can germinate and expand their leaves and ripen their fruits in a few days of polar summer, are satisfied with a sum of 90 degrees. Barley, which of all the cereals advances farthest in the direction of the pole, enters its period of growth when the temperature has exceeded at least 9 or 10 degrees, and in order to arrive at maturity, demands a sum of 1800 degrees, whatever may be the average of the seasons it passes through. According to Seynes, wheat commences vegetation at 12 degrees above zero, and receives about 3600 degrees till the time of harvest, which varies according to the climates. The maize, a more southerly plant, requires a sum of 4500 degrees, and its starting-point is at the 55th degree of the thermometer; while the vine demands 4850 degrees, commencing with the 50th degree of the scale. Finally, Alphonse de Candolle considers that the date-tree needs a total heat of about 9200 degrees before it can ripen its fruit. The greater

Fig 165.—Polar Limits of the Holly, Ash, Beech, and of Chamærops humilis.

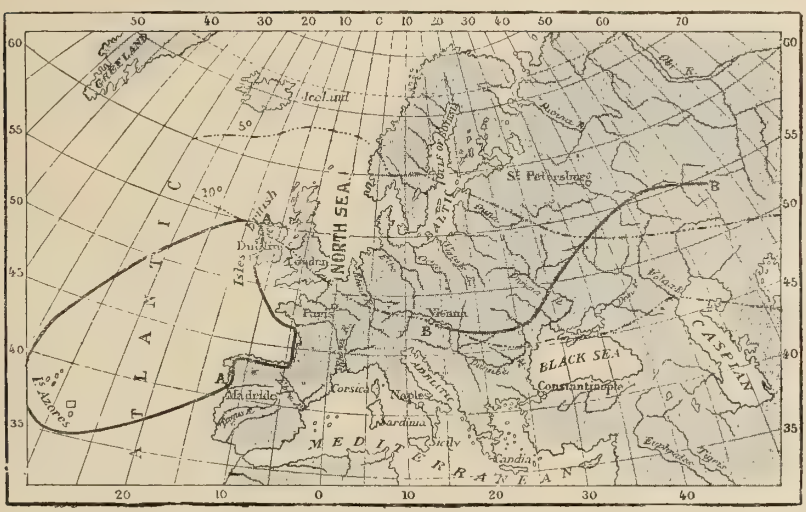
A A Polar Limits of Holly
B B " of the Ash.
C C " of the Beech.
D D Polar Limits of Chamærops humilis.
-------- Isothermal Lines at 5° and at 10°.

part of the plants of the temperate zone can support cold of 28, 29, or even 36 degrees without their vital force being destroyed, but none can germinate or grow at temperatures below freezing-point. In the mountains saxifrages and soldanellas flourish even under the snow, but the water which supplies the roots and the air which surrounds their stems have a temperature above freezing-point. The researches of Alphonse de Candolle show that the growth of vegetable species commences on an average at 41 degrees in the regions of western Europe. Still we cannot say that in the starting-point of the growth of each plant we have an absolutely fixed limit, like the degree of temperature at which metals begin to melt; it is probable that, according to their vigour and their various surrounding conditions, certain individuals are quick and others slow to spring forth. Besides, under climates always spring-like, as that of Madeira, plants only commence their annual development after having reposed during a certain period, in order to have time to renew their tissues. Thus the vines of Madeira only begin to vegetate towards the end of March, when the temperature is already 64·4 degrees centigrade;

though during all the winter the average heat, which does not descend below 63·5 degrees, would have been more than sufficient to develop the vine and cause its fruit to ripen. In the same way on the plateaux of tropical countries, where a perpetual spring is enjoyed, the plants repose during the winter period; they preserve their leaves, but they do not produce new ones; they develop flowers and fruit, but only those of which the buds have already germinated during the summer.

The relative dryness or moisture of the various countries is also among the principal causes of the limitation of the areas of species: a too rainy atmosphere drowns the plant; the want of aërial vapours burns it up. Thus many plants do not penetrate into the dried-up steppes of Russia, where the temperature would otherwise be favourable to them; others cannot be acclimatized to the west of Great Britain, where the annual quantity of rain is enormous. The species which are developed in these moist countries have a charming freshness; the aspect of the

Fig. 166.—Polar Limits of Dabœcia polifolia and of Amygdalus nana.



AA Polar Limits of Dabœcia polifolia. ---- Isothermal Lines at 5° & at 10°.
BB „ „ of Amygdalus nana.

trees and meadows shows that they are incessantly watered by rain. In tropical countries, where the annual heat is always sufficient to cause the plants to arrive at maturity, it is the influence of moisture which preponderates. The limits of the zone of rains are also the limits of the zone of vegetation.

A point of very great interest in connection with this subject is the biological condition of the algæ flora in the Arctic regions, which have been specially studied by V. B. Wittrock and Professor Kjellman. Algæ which conclude their existence in a single year are either wanting, or at all events very few. Nearly all Arctic algæ live several years, and in order that they may be able to effect the work of propagation and nourishment with the little supply there is of heat and light, their organs are in operation during the dark as well as the light season. Whilst wintering at the northernmost part of Spitzbergen in 1872-73, Kjellman observed in the middle of the winter, viz. at a time when the sun was lowest and the darkness therefore most intense, that a considerable development and growth

of the organs of nourishment took place; while, as regards the organs of propagation, he found that it was just at this season that they were most developed. Spores of all kinds were produced and became mature, and they developed into splendid plants. The Arctic algæ therefore present the remarkable spectacle of plants which develop their organs of nourishment, and particularly their organs of propagation, all the year round, even during the long polar night, growing regularly at a temperature of between $-1°$ and $-2°$ C., and even attaining a great size at a temperature which never rises above freezing-point.

The result at which Kjellman arrived with regard to the development of the Arctic flora was this, that the algæ flora of the Arctic Ocean is, contrary to the phanerogamic flora, not an immigrant flora, but that its origin lay in the Polar Sea itself. This theory is, he believes, proved by the facts that (1) the Arctic algæ flora is rich in endemic species, these being not fewer than 37, or 22 per cent. of the whole flora; and that (2) there are many species found both in the Northern Atlantic and the Pacific Oceans a large percentage of which reaches very far north in the Arctic Sea, and which have attained a high degree of development there, being characteristic algæ of the Arctic Ocean. That the endemic species owe their origin to the Arctic Ocean cannot be doubted; and that the species referred to under (2) have been originated there and gradually spread to the other two oceans is more than probable. If this be so, Kjellman estimates the number of species whose origin must be referred to the Arctic Ocean at 100, *i.e.* about 60 per cent. of the entire algæ flora.

Light, as well as heat, is one of the most important conditions of vegetable life. Alphonse de Candolle has ascertained by direct experiments that of two plants sown on the same day, that which is exposed to the solar rays is contented with a smaller amount of heat to develop and ripen. It is thus to the greater intensity of light that a number of mountain species owe the rapidity of their growth, their brilliancy, and the relatively large size of their flowers. On all the mountain-tops of the south of Europe the Alpine plants, in order to grow and come to maturity, are satisfied with a much less amount of heat than the species inhabiting the plains situated at a great distance to the north.

Another fact, much less studied, but perhaps not less important than that of heat, contributes to the unequal distribution of plants: this is the chemical power of the solar rays. It would be quite natural to think that this power increased from the temperate to the tropical zone proportionally to the force of the sun; judging, however, from several photographers who were not able to obtain their proofs so easily under the dazzling sunlight of South America as in the changeable climate of England, it was till quite recently doubted whether the chemical power of these rays increased in the direction of the equator. At length Mr. Thorpe has removed these doubts by observations made at Para, on one of the arms of the river Amazon. The averages of chemical intensity are from 7 to 34 times greater at Para than at the Kew observatory; but while in England this intensity slowly increases and diminishes each day without abrupt transitions, under the tropics it changes in the most sudden manner in the rainy season. When the showers accompanied by electrical discharges fall all at once from the sky, the chemical intensity ceases completely, and then acts again with great force as soon as the storm has spent itself.

Under temperate climates abrupt variations of chemical light are less frequent than in tropical countries; but nevertheless they are much stronger than the variations of heat. In fact, from the month of December to the month of June

differences from 1 to 20 have been ascertained in England and Germany in the activity of the luminous rays. This is because the influence of these rays does not only depend on the position of the sun in the heavens, it increases or diminishes according to the innumerable changes which are effected in the atmospheric ocean. Thus the whitish clouds which veil the sky like light draperies give a greater chemical force to light, and the effects make themselves immediately felt upon nature; but if the clouds thicken, and interpose themselves in black masses between the sun and the earth, then the action of the luminous rays immediately decreases, and a sudden ebb succeeds to the full tide of vital force which was distributed from the sky.

With the perturbations in climate which produce the incessant alteration of clouds, fogs, and invisible vapours, we must include the changes caused by the myriads of grains of dust and floating germs, and by all the emanations of carbonic acid, hydrogen, and ammonia, which escape from the earth and disturb the purity of the air. It is thus very difficult, in the present state of science, to indicate approximately, even for the best-known countries of western Europe, the relative value of the chemical action exercised on an average during the year by solar rays. It would be still more difficult to trace on the circumference of the globe isochemical lines analogous to the isothermal lines. This is a conquest of science reserved for future observers. Nevertheless, the researches of Messrs. Bunsen, Roscoe, and other savants, have already proved that the power (*l'actinité*) of the solar rays is subject to greater modifications than the heat; the lines of equal chemical climate must consequently much exceed the lines of equal temperature in their curves and abrupt windings. If there are no chemical winds like moist and warm winds, it is precisely these latter which incessantly modify those changing masses of vapour in the atmosphere which alternately diminish and increase the force of the sun's rays.

Thus the extraordinary difference between the floras of two neighbouring countries, the temperature of which is visibly the same, may perhaps be explained by the enormous influence which the state of the sky exercises. Thus flowering shrubs do not grow in the Faröe Islands, and we only see brushwood and meagre bushes there, although the temperature is only one degree below that of Carlisle, in England, where we have fine forest vegetation. In fact, if the heat is the same, the light is very different. The sun's rays which penetrate the mists of England are in great part absorbed by the thick fogs of the Faröe Islands, which the ancient navigator Pythias believed to be a sort of "marine lungs," where air, water, and mud were confusedly mingled. Perhaps, too, it is to a greater chemical and luminous force developed during the long days that we should attribute the singular rapidity with which the plants of the north shake off their winter sleep at the time of the sudden invasion of spring. In a few days all the trees are covered with buds and leaves, while months elapse in more southerly latitudes between the budding forth of the different species. Not only do the plants indigenous to the north, but those also which are acclimatized in these regions, open their buds much sooner than might be expected according to the habits of these plants in southern countries. At St. Petersburg, under the 60th degree of north latitude, it has been ascertained that the budding of the birch-tree, the first signs of spring-tide life, precedes that of the lime-tree by only five days, and the flowering of the common *Alchemilla* by eighteen days, while at Breslau, situated 8 degrees farther to the south, the intervals are respectively fifteen and fifty-one days. "The farther we advance to the north," says Alphonse de Candolle, "the more does light replace warmth in utility."

Thus we see the questions relating to the natural areas of plants are most complicated, and that it is not without very long and patient study that botanists are able to determine precisely what are the natural history and distribution of each plant, and what are the manifold causes which arrest its extension beyond certain limits. Not only must we take into account the alterations of temperature, of light, and of the chemical power of the solar rays, but it is necessary also to estimate the effect of all meteoric phenomena, to appreciate the influence of dryness and moisture, of long rains and passing showers, of exposure, of different altitudes, and of inequalities of the ground. Besides all these conditions of the climatic circumstances, it is necessary also to know what is the vitality belonging to the plant itself, what its power of distribution over the earth, and the strength of its resistance to the destructive agents which surround it. It is also important to know the former distribution of continents and seas in geological times, so as to learn what obstacles, such as arms of the sea or chains of mountains, may have arrested the distribution of certain plants over more extended areas. Each plant has its separate history, its peculiar characters and geographical distribution, and thus it is to the extreme diversity of the conditions of existence that we owe the wonderful variety which is presented by the grouping of species on the surface of the globe.

The relations of plants to their environment forms the subject of an exhaustive paper recently contributed to *Nature* (April 29, 1886) by an anonymous writer, who remarks that in plants are found great differences of constitution, affecting their internal structures, external form, and habit of life. "The differences of structure and form at first seem likely to be correlated, and no doubt such relation to a large extent does obtain, but still it is not at all exact, differences of form occurring between plants whose internal structure closely agrees. The study of the environment of the particular plant enables us to see that this must be taken into account in tracing the changes that have made it what it is, each plant having a power of adaptation to circumstances which determines the form which it assumes, which modifies, though with extreme slowness, its internal structure, and which leads in course of time to the recognition of new species.

"Looking at plants from this point of view, we notice at once great differences between those which flourish in water and those whose home is on land. These, again, show diversities between those whose habit is terrestrial and those which are epiphytic, while others are noticeable whose habit of life is more or less completely parasitic, and whose constitution and structure are much modified in consequence.

"A typical land plant will be seen to consist of a stem, branching continually, bearing a variable but usually very large number of leaves, and continuous below, with a root or system of roots embedded in the soil. The stem will be characterised by a great development of wood, rigidity being thus secured. The leaves will be noticeable especially for their great extent of surface in relation to their bulk, and will show, generally on their under surfaces, though very frequently on both, a large number of stomata. The roots will be woody, like the stem, and towards their ultimate terminations will be found to bear a varying number of delicate root-hairs, by means of which they are enabled to discharge their special function of absorption of water.

"This plan of construction is considerably deviated from by plants whose habit is aquatic. The stiffness so essential to a land plant, which has to resist storms of wind, is not at all essential to a water one, which has rather to adapt itself to varying currents of water. More flexibility, and that of a rather different kind, is

needed by the stem. We find, consequently, that the rigidity of an aquatic plant is mainly arrived at by the development of turgid parenchymatous tissue containing typically large intercellular spaces, while the woody tissue largely disappears. The intercellular spaces in most cases form a very elaborate system, as may be seen on examining the petioles of the large white water-lily (*Nymphæa alba*), the stem of the common mare's-tail (*Hippuris*), or the whole plant of different species of Potamogeton. The number of the fibro-vascular bundles is much less than would be the case in the stem of a land plant of similar dimensions, but the most noticeable difference is the relatively much smaller amount of woody tissue in each bundle. This difference of internal constitution may be connected also with a functional difference associated with the environment. The woody tissue of a plant is concerned with the transmission of water upwards from the roots to the leaves. In the case of an aquatic plant this is not needed to anything like the extent to which it is in an ordinary tree, and hence a further reason for the disappearance of woody elements. Nor is it only the stem which has been affected by the habitat. The character of the root will be found to vary. This is best seen in noticing the effect of allowing the root of an ordinary land plant to come into contact with a quantity of water. By its constitution it is fitted to absorb only the hygroscopic water surrounding particles of soil. The first effect of the contact with excess of water is to cause the root to perish; but after a time new roots are developed which can utilise the moisture they now are in contact with, and which in turn are unable to avail themselves of the hygroscopic water which before was necessary. Both kinds of roots may be seen sometimes on plants which have been growing close to pipe-drains, some having penetrated the drain, and so come into contact with water in quantity; others remaining unchanged, and utilising only the water of the soil. Such differences may be noticed also in the case of hyacinths, grown some by water culture in glasses, others in ordinary earth. The former roots are larger and more succulent than the latter. A difference also may be seen in the development of the root hairs, though a very definite statement about this can hardly be made. Still, in allied species and often in individuals of the same species, the hairiness of the roots increases with increasing sunlight, dryness, and airiness of the spot in which the plants are growing.

"The leaves also undergo much structural modification. Many plants have leaves which are totally submerged, and these are able to resist the action of the water, which would soon destroy ordinary leaves, whose constitution fits them to live only in air. Some amphibious plants show this peculiarity well. They grow generally in marshy places, or on the banks of streams, by which they are often submerged. Such a plant, having its land form, possesses leaves which die on being submerged, but later it puts out other leaves which are not injured. In *Lycopus Europœus* and in *Lythrum Salicaria* there is also a histological difference between the stems grown in water and those grown in air. Two layers of cells containing no chlorophyll are developed in the watery specimens deep down in the cortical parenchyma. The outer layers of tissue perish, and these new cells then serve to protect the tissues within. In the leaves of water plants also, other peculiarities are noticeable. Generally chlorophyll is developed in the epidermis, a fact which is perhaps connected with the slight amount of evaporation taking place. The position of the stomata and their relative number in different cases is also closely connected with their habit of life. This may be well seen in Marsilea, whose leaves, though generally raised above the surface of the water, are sometimes to be found floating on the surface. The aërial leaves have stomata on both upper and under surfaces,

but the swimming ones have them only on the upper surface, and have then three times the number that the same surface of the aërial leaf possesses. It is easy to show that the change is the result of the change in the environment, for if a piece of the plant, possessing quite young leaves, be submerged and kept under the surface, the young leaves will develop into swimming-leaves, and not aërial ones. In other water plants with large floating leaves the same disposition of stomata may be seen. Generally on sub-aërial leaves it is the lower surface which shows them in far the larger quantity. The environment of the plants then seems to have a great influence on their distribution, that arrangement being followed which is best suited to keep the stomata dry.

"A curious adaptation of structure to environment is seen in the roots of the epiphytic orchids and aroids. These are aërial in habit, hanging freely downwards. Not coming into contact with water in the same way as either aquatic or terrestrial plants, they have no root-hairs. There is a development of tissue met with in them which enables them to absorb and avail themselves of the moisture in the atmosphere. Instead of the usual single-layered epidermis, they are covered by a many-layered velamen made up of numerous cells fitting closely together, of the description known as tracheïdes. The usual cuticle or secretion from the outer walls of the epidermis, which is always very little developed in roots, is here altogether absent; the membranes of the cells are usually colourless, and the cells themselves contain air. This layer absorbs water quickly, supplying the plant with moisture.

"The influence of the environment on the forms of leaves, as well as on their structure, can be well seen also in aquatic plants. The swimming-leaves show certain general resemblances, their form being more or less rounded, and not as a rule lobed or cut; they are, too, usually of fair dimensions. In the case of submerged leaves we find differences which are connected with the conditions noticeable in the water. Thus, in a rapid stream they are generally long and very much divided, while in stagnant water this is not the case. Three species of the genus Ranunculus especially exhibit a gradation in this respect. *R. divaricatus* is a denizen of stagnant water; *R. aquatilis* is found in slowly-flowing streams; *R. fluitans* in rapid ones. The divisions of the leaf are longest in the last case and shortest in the first, the second being intermediate. *R. aquatilis* is an amphibious form, and shows well how environment decides the character of the adult plant. When growing in a pool it has its leaves in fairly long divisions, the lobes being rounded and the internodes long. If the pool should dry up, it changes gradually, the new leaves being less divided and the divisions becoming flattened, while the nodes are nearer together. The epidermis, which in the water form had almost square walls, now becomes serpentine. Growing so, it produces in due time its flowers and seeds, and these latter reproduce the land form. If the pool again becomes filled with water, a reversion speedily takes place, and again the characteristics of the water form are seen. The two are, in fact, easily converted from the one into the other.

"Not only is the correspondence between environment, form, and structure seen in the species of Ranunculus already alluded to, but the whole genus can be divided into two sections, those of terrestrial and those of aquatic habit, so nearly allied to each other on all points of so-called systematic importance that they are now included together under the common name Ranunculus, and yet extremely dissimilar in form and structure of the vegetable parts. The same difference in amount of woody tissue as has been alluded to above can be seen most strikingly

by comparison of sections of the stem of *R. repens* with those of the stem of *R. fluitans.*

"Turning now from aquatic plants to those which, though alike terrestrial, are yet situated amid very different surroundings, the effect of the environment can easily be traced. Take, first, the plants which inhabit regions in which habitually the air contains very little moisture. These may be affected in several different ways, the most conspicuous modification perhaps being the different forms of succulent plants, such as *Mesembryanthemum.* In these the leaves have lost the usual ratio between surface and bulk; they are now thick and fleshy, their internal parenchyma being very succulent or pulpy; their outer layers leathery, with comparatively few stomata, and a great reduction of the system of intercellular spaces typically found in the leaf. Their environment has led to such a structure as will enable them to make the most of the limited supply of moisture, great facilities being seen for storing it, and precautions taken against its escape. Similar adaptations, but affecting the stems and not the leaves, are found, *e.g.*, in the branching fleshy Opuntias, while we have also large, thick, fleshy leaves in the aloes and agaves of such regions. The genus Euphorbia has some strange representatives here. There are several hundred species of this genus, inhabiting all parts of the world, and all characterised by the peculiar structure of the flower familiar to us in the common spurge of our gardens. The great majority of the species are annual or perennial herbs, with slender unarmed stems bearing great numbers of scattered, sessile, simple leaves. The comparatively few members of the genus which inhabit the regions of little moisture have become so extremely modified in their vegetative parts as to closely resemble cactuses. *E. canariensis* especially has taken on this peculiar habit, developing enormously its stem and branches, the former becoming in some cases 20 feet high, and ceasing to produce leaves, while the branches are plentifully supplied with prickles.

"A curious modification in the cells of the leaf is seen sometimes in some species of Oxalis. In plants grown in well-shaded spots the cells of the pallisade parenchyma are not so much elongated as in those exposed to more light, but are more conical. In the beech too a similar difference is noted. In the sun the leaf is smaller and thicker, and has several layers of pallisade parenchyma, while in the shade it is large, but thin, and the pallisade layer is single.

"Looking still at terrestrial plants, the general character of the vegetation in different regions illustrates well the general correspondence between environment and structure. In the tropics we find vegetation luxuriant, huge trees with evergreen leaves, masses of interlacing climbers, a great tendency of the smaller plants to become shrubby, even some annuals simulating the bushes of temperate regions; the presence of palms, tree-ferns, &c. Higher in latitude these disappear, bushes are more numerous; the trees become less luxuriant and more compact, the leaves smaller and more rigid; annuals are found in larger proportion, while mosses and lichens make their appearance. Still higher, where the influence of winter begins to be felt, the trees have as a rule deciduous leaves, which do not cover them for more than half the year. Where the leaves remain evergreen, as in the Coniferæ, they are specially constructed to resist cold, being strongly cuticularised and altered in form so that the ratio of surface to bulk is much lessened. In the pines especially they are much elongated, becoming almost needle-like in shape. Their structure is adapted especially to check loss of water by evaporation, and to protect the delicate parenchyma of the interior from the access of the cold.

"Various modifications of structure accompany also a parasitic habit of life.

Here the effect of the environment must be taken to include all the various interferences with the normal habits of plants brought about by the changes in the mode of nutrition which the parasite now pursues. The modifications will be seen to be greater the more complete the parasitism. We may consider what are perhaps the most striking cases, those found among flowering plants. Of these we have certain Scrophulariaceæ which show but little modification. They take only part of their nourishment from their hosts, being furnished with means of living exactly like other plants. The dependence of the different species of Orobanche on the host is more complete. The outward form of the plant is there: the long stem, bearing small leaves. In accordance with the mode of nutrition, all the food being absorbed from the host, the power of absorbing food or obtaining energy from without the latter has gone; the leaves contain no chlorophyll, and are consequently brown and shrivelled. In Cuscuta the process of degradation has gone still further, even the leaves having disappeared. The degradation does not affect merely the vegetative structure, but the reproductive organs also suffer, as may be seen in the common mistletoe. This change, however, seems only incidentally to be connected with the environment, being rather the result of the disturbance of the constitutional equilibrium brought about by the changes in nutrition.

"A comparison of lower forms of parasitic habit with others which, though about as high in the scale, do not depend on a host for support, reveals similar degradation brought about by the nature of the mode of life. Their power of independent growth has much decreased, their cells often appear to contain no nuclei, or these are made out with difficulty; they have no chlorophyll, nor any of the other colouring matters which are present in the non-parasitic forms.

"Some curious modifications of structure are associated also with different climbing plants. These are not of so general a nature as those already alluded to, being noticeable only on particular species. In *Ampelopsis hederacea*, and in *A. Veitchii*, the curved tips of the tendrils, after touching a surface, form adhesive disks, which secrete and pour out a resinous cement which attaches the tendril to the surface. *Bignonia capreolata* has a similar but more elaborate development, while *Ficus repens*, which climbs like the ivy by rootlets, exudes similar material from its rootlets, this being somewhat of the nature of caoutchouc."

White flowers are in general more fragrant than others; then follow the yellow, the red, and the blue, in the order here given. Plants with odoriferous leaves, aromatic fruits, and perfumed wood are found as a rule only in the hot regions of the globe.

CHAPTER LIII.

PARTICULAR HABITATS OF SPECIES.—SALT-WATER AND FRESH-WATER PLANTS.—LITTORAL SPECIES.—PARASITES.—TERRESTRIAL SPECIES.—INFLUENCE OF THE SOIL ON VEGETATION.—PLANTS ASSOCIATED TOGETHER.—SEAWEED.—EXTENT OF AREAS.

MOST plants occupy but a small portion of the space circumscribed by the general limits which climate has traced for their habitation. This is because, according to their nature, certain special physical conditions are also necessary to them, without which germination and growth are impossible. Thus, to cite the most striking example, the aquatic vegetation is composed of species quite different from those which grow on dry land. Excepting in the undecided zone alternately covered and laid bare again by the waters, and where plants called amphibious are developed, the two floras are absolutely distinct. If it be true, as certain botanists think, that some kinds of marine algæ produce terrestrial plants of the mushroom tribe, the germinative power would in this case only exercise its force to transform completely the structure and appearance of the plant.

The contrast of the floras is scarcely less absolute between fresh and salt water than between the seas and the continents. The ocean has its special plants, some floating freely over the waves like the *sargasso*, or "grapes of the tropics," others clinging to the rocks and ledges of the shore. The rivers, lakes, and ponds of fresh water have also their particular species: potamogetons, swaying like long hair at the will of the current; water-lilies spreading their broad leaves, of an emerald green, over the transparent water; innumerable confervæ, forming a continuous layer of vegetable matter on the surface of the pond, resembling from afar the surface of a meadow. The plants which flourish equally in fresh and in salt water are very few, and usually are only met with in the estuaries of rivers where the tide ascends, and where the mingling of the waters takes place. As to the turbaries, they are entirely composed of a particular set of plants which press against each other, and contain water in their interstices as in an immense sponge. The vegetation of the shores themselves presents one of the most striking contrasts according as they surround fresh waters or seas saturated with saline substances. Thus the deposits of the ocean, the sand or clay of which is strongly charged with sea-salt, produce in abundance sassify, samphire, thrift, and other plants generally of a somewhat dull appearance, which give a special physiognomy to the shores. In the interior of continents a similar flora is found only around salt lakes and in districts where springs of salt water rise from the earth; it is indeed the sight of these plants which has often urged miners to pierce the soil in the hope of discovering banks of rock-salt hidden in the depths of the ground. Other kinds

of plants seem to require not the sea-salt, but the vapours which escape from it. Such is the case with one of the most charming heaths, *Erica sylvatica,* which grows in the low plains around the Gulf of Finland, the Baltic Sea, the North Sea, the Channel, the Bay of Biscay, and which is found also on the coasts of Spain and Portugal, without ever having been met with at more than 150 miles inland.

The atmosphere possesses its special vegetation as well as the waters. Certain plants demand from the earth simply a support, and draw from the air all the nourishment they require. Multitudes of other species never grow on the bare earth, but fix themselves on the hidden roots, stems, or branches of other plants which serve as a nourishing soil to them. Lianas of all sorts, orchids, passion-flowers, bignonias, euphorbias, apocyneas, ferns, mosses, and lichens, group themselves thus into aërial forests, and, mixing with the foliage of the trees which bear them, adorn them variously with garlands, bouquets, tufts of verdure, or flowers. Upon these parasites other parasites live, and in certain tropical forests, where each tree is a whole world of plants, the foliage of the interlacing vegetations presents such a confusion of forms that the eye of a most experienced botanist alone is capable of distinguishing them.

Finally, even the interior of the soil has its particular flora, composed of truffles and other cryptogams, which only receive the influence of the atmosphere through the fissures of the earth. Grottoes, too, to the very end of their labyrinths, have plants which shun the light, and in the forests certain species of vegetables, almost always white or pale-coloured, hide themselves in the shadow, at the foot of the great trees, and raise their delicate stems above the carpet of moss and dry leaves.

Among the much more numerous plants which bury their roots in the ground, and wave their leaves in the open air, there are some which prefer a sandy soil; others grow best in a limestone country, others again on gravel, stiff clay, or in the fissures of granite. Some botanists have even attempted to class plants according to the chemical composition of the soil they affect. It is certain that many kinds, even without counting those which grow on salt lands, are met with exclusively on their favourite soil. The chesnut, the purple foxglove, and the common broom delight in a siliceous soil; the *Carex arenaria,* and other ordinary plants of dunes, and, under tropical climates, the cinnamon-tree, require almost pure sand; limestones have also their species, which do not thrive elsewhere. Nevertheless, it does not seem to be so much on account of the substances which they contain, but rather because of their physical properties, such as hardness, density, and porosity, that these different soils nourish particular species of plants. If the composition of the rocks remain the same, but become at the same time more disintegrated, allowing the outer air and moisture to penetrate more readily, the vegetation will instantly change, and we shall see species appear on the chalk or clay that we might only expect to find on sand. Thus when the botanist leaves a country where, in consequence of the resemblance of the physical conditions of the soil, the same rocks are always covered with the same vegetable carpet, he perceives with astonishment that species forsake the soil which he believed to be necessary to them. Of forty-three plants, which Wahlenberg had only observed on the chalk in the Carpathian mountains, he found twenty-two on the crystalline rocks of Switzerland and Lapland. Similarly, of sixty-seven species, which in Switzerland grow exclusively on calcareous ground, thirty-six are found in the surrounding countries on soils the chemical composition of which is quite different; and one might believe that further researches would result in reducing still more the number of plants which are absolutely peculiar to one kind of soil. Besides, as

M. Theodore de Saussure has proved, the tissue of many plants seizes hold indifferently of the most abundant and most soluble substance which is found round the roots : the ashes of the Norwegian fir are not of the same composition as those of the fir-tree of the Jura.

Not only do species of plants know how to choose the soil that best aids their growth, but they also seem to exercise a kind of discrimination in their associations with other plants. Either it is that they demand exactly the same physical conditions of soil, or else that they seek a shelter. Without speaking of the parasites which have no independent life, a number of "social" species are always near together, and by the harmony of their grouping impart some sweetness and friendliness to nature. Thus the approach to a forest is announced to the traveller by little plants and shrubs which do not grow in the open country ; the gay colours of blue corn-flowers and poppies are always mingled, at least in western Europe, with the light ears of corn; herbs that agriculturists qualify as "weeds" associate themselves invariably with the crops in our fields; plantains and potentillas grow together on the roadside and, so to say, under the very feet of men; the châlets of the Alps and Pyrenees are surrounded with nettles and docks which rise in tufts above the short grass of the pastures. Finally, the grassy steppes, American prairies, savannahs, or pampas are nothing else than immense colonies of social plants. By contrast, the deserts with their burning soil often present over vast areas only the meagre verdure of a single species of plant. Thus the clay of the plateau of Utah only allows the roots of an *Artemisia* to penetrate into its fissures, and over a great part of their surface the deserts of New Mexico and Arizona have as their sole vegetation only the gloomy and fantastic candelabra of the giant taper.

The ocean, like the earth, has its monotonous tracts of plants; there are whole fields of sargasso (*Fucus natans*), which are found in the centre of several maritime basins, and notably in the immense triangular space comprised between the Antilles, the Gulf-stream, the group of the Azores, and the archipelago of Cape Verde. Columbus crossed these parts filled with marine plants, and for his companions it was not the least among their terrors to see these long runners which retarded the progress of the ship, and made the unfathomable sea appear like an immense marsh. Interlaced in floating islands and islets which follow each other in interminable processions, these plants change the surface of the ocean in certain places to a kind of meadow of a greenish-yellow or rust-colour; the waves raise these masses in long undulations and surround them with borders of foam; fish sport by hundreds under this vegetation, which shelters them from the sun; myriads of little animals, crabs, shrimps, serpulæ, and shells run, climb, and incrust themselves on the interlacing stems of these migratory forests, and traverse with them the extent of the seas.

It was formerly believed that this floating weed of the Atlantic had been detached by the breakers from the shores of the Antilles and Florida, and then carried hundreds of leagues from land by the Gulf-stream ; all these masses borne along the course of the waters would be at last united, as in the centre of an eddy, in the space surrounded by the waters of the great circular tourbillon of the North Atlantic. This notion was not correct; the fuci of the ocean originate and are developed on the surface of the waters. Neither roots nor the least indications of bulbs can ever be discovered in them which could have clung to the earth and which the waves might have torn away. Each stem is abruptly terminated at its lower extremity by a kind of cicatrice, and is evidently only a detached branch of another plant; vesicles full of air, which have given this fucus the name of the "tropical grape," serve as floats to sustain it on the water, while hundreds of

foliaceous membranes rise vertically above every islet of the weed, so as to absorb the quantity of air which these organisms require in order to grow and propagate themselves.

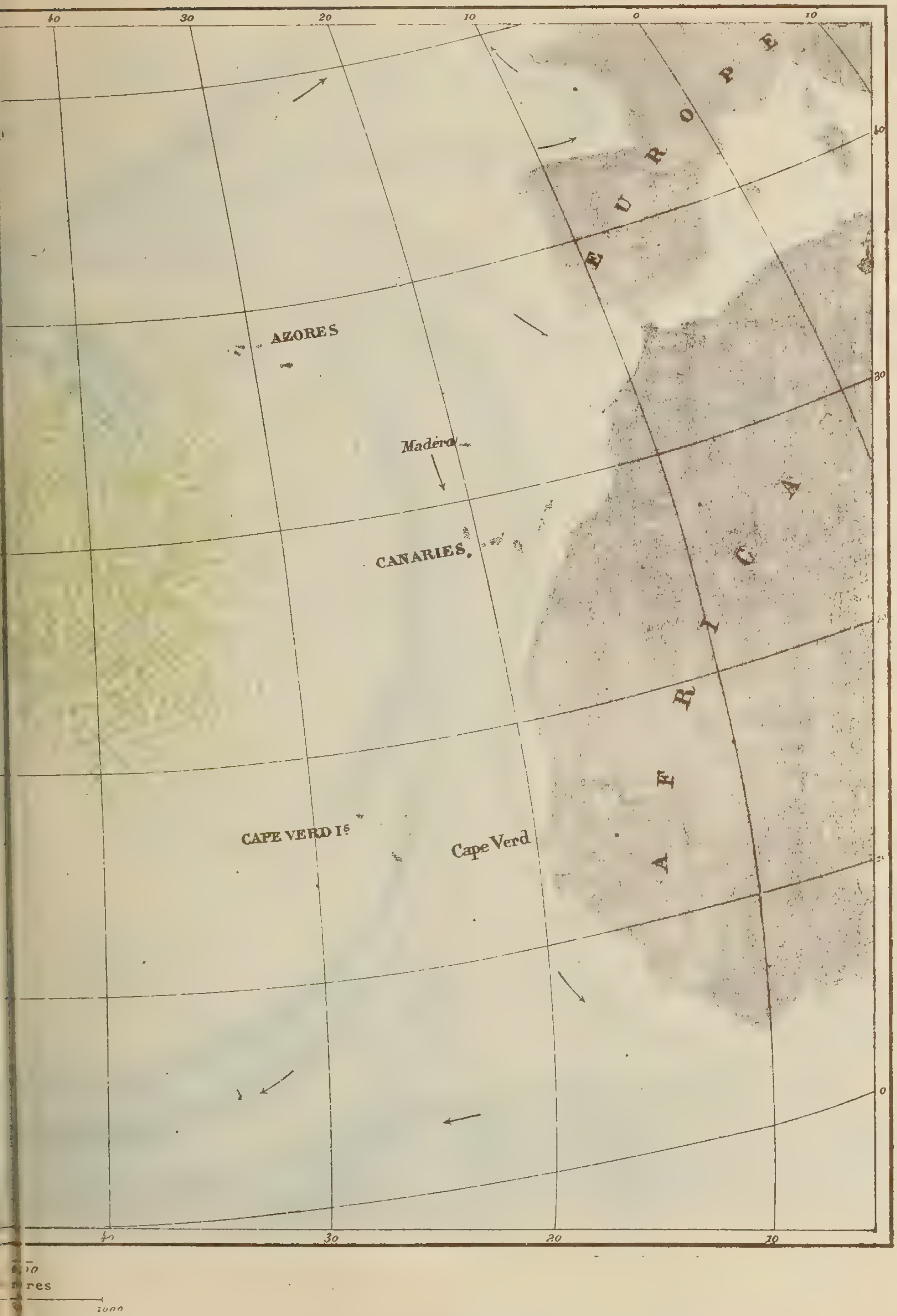
It is true that all these meadows of seaweed circulate under the influence of the winds in the eddy formed by the Gulf-stream and the equatorial current; but instead of having been brought by these marine rivers, they are, on the contrary, arrested by them, and accumulate in rows along their inner shores. Only a small number of plants penetrate into the sea of the Antilles and Gulf of Mexico by channels between the islands. The Sargasso Sea, properly so called, of the North Atlantic is comprised between the 16th and 38th degrees of north latitude, and extends from east to west, from the 45th to the 75th degrees of longitude. In this immense space the weed constitutes two separate masses, as if a branch of the equatorial current bent towards the north, and thrust back to the right and left the meadows of seaweed. We can venture to estimate the surface of this sea of weed at more than 1,600,000 square miles; in the other oceans, the North and South Pacific, and South Atlantic, it covers enormous surfaces. If ever the agriculturists of Europe and America put into execution the idea of M. Leps, who proposes to load ships with this weed, they would be able to provide themselves amply with this manure for the improvement of their crops.

It appears, from the numerous comparative studies of Alphonse de Candolle, that the general form of the area occupied by each plant is that of an ellipse a little elongated from east to west under the temperate, and from north to south under the tropical, latitudes. This natural arrangement is easily understood, for in the various zones the greatest diameter of the ellipse ought to indicate the direction in which the climate presents most equality over a more considerable extent. It is a remarkable fact that the area occupied by the species is the more extensive the simpler is their organization, and that they likewise seem to possess a greater antiquity. Thus the cryptogams, which are the least developed plants, occupy the largest surface. In the same way marine species have an average area more extensive than that of the terrestrial species; herbaceous plants occupy a more considerable area than trees; and finally, the annual phanerogams have a country of larger dimensions than the perennial and woody phanerogams. "The area of plants is in inverse proportion to the complication of their structure." It is also very remarkable that from logical causes, probably anterior to the present state of the globe, the average area of species diminishes gradually from the Arctic Pole in a southerly direction.

No kind of flowering plant, not even the nettle and purslane, the most faithful of the companions of man, inhabit the entire earth. Only eighteen species are reckoned which show themselves at the same time on half the terrestrial surface, and the total number of known plants each of which occupies a third of the globe, is estimated at only a hundred and seventeen. On the other hand, there are plants which botanists have never discovered except in a ravine or on an isolated promontory. The many islands scattered in the ocean—St. Helena, Tristan d'Acunha, Juan Fernandez, Madeira, and the Galapagos—possess the greater part of these solitary plants, not to be found elsewhere. But there are also parts of the continent where the species have for their whole domain a district of a few leagues or acres, which may be regarded as a sort of continental island. As to the general superficial extent of the areas, it would be, according to Alphonse de Candolle, about the hundred and fiftieth part of the earth's surface, that is to say, nearly 120,000 square miles.

Ocean. SARCAS

LONDON.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CHAPTER LIV.

CONTRAST OF THE FLORAS IN THE DIFFERENT PARTS OF THE WORLD.—INSULAR AND CONTINENTAL FLORAS.—INCREASING RICHNESS OF VEGETATION IN THE DIRECTION FROM THE POLES TO THE EQUATOR.

CONSIDERED as a whole, the continents themselves, like the more restricted areas, present remarkable contrasts between their floras. Thus taking their disproportions as to extent into account, the New World appears to be much richer in species than the Old. This fact is explained by the general disposition of the two Americas, and its chains of mountains, almost all running in the direction from north to south. In consequence of the position of the Andes and the Cordilleras, the mountains of Brazil, the Alleghanies, the Rocky Mountains, the Sierra Nevada, and the Coast Range of California, it is found that under each latitude the most various climates succeed each other on the opposite slopes, and in consequence different species are developed in each of these distinct climates. In the Old World it is not thus, for most of the mountain-chains—the Pyrenees, the Alps, the Balkans, the Caucasus, Mont Taurus, the Himalayas, the Karakorum, the Kuenlun—stretch in a direction from west to east, and consequently the climates and floras are not modified in the same direction, but by very gradual transitions. On the other hand, Africa, notwithstanding the situation of the greatest part of its mass under the torrid zone, is relatively less rich than the other continents in species of plants. This is explained by the general uniformity of the country, the few high chains of mountains, and the very slight moisture of its winds. But the southern extremity of Africa, the English colony of the Cape, is exceedingly rich in plants.

In the tropical regions flowers of the brightest hues are seen chiefly on large forest trees. In the subtropical zone the shrubs as a rule display the greatest show of blossom, while in the temperate zones neither trees nor shrubs can pretend to rival the splendid colours with which field and meadow are carpeted. By a surprising contrast, the regions of shrubs and low grasses are precisely those in which flowers are the most conspicuous feature in the general aspect of nature. The English meadows, the heaths of the French landes, the steppes of South Russia, display far more brilliancy and variety in their colonies of flowering plants than the primeval tropical forests, or even the savannahs, which are everywhere pervaded by a uniform green tint.

On the supposed profusion of brilliant flowers in tropical regions, the naturalist H. O. Forbes remarks that "this is just one of the products of the 'summer of the world' that the traveller fails to see unless he search very well and very closely. The great forest-trees are too high for one to be able to see whether they

bear either fruit or flowers. It is only on rare occasions—and then the sight repays him for many a weary mile—that he alights on a grand specimen, whose top is a blaze of crimson or gold. More generally he knows that some high tree, which of many it is often very difficult to say, is performing its functions, by seeing broken petals or fallen fruit spread over yards and yards of the ground.

"Of the great mass of lower vegetation nothing is seen but green foliage. Hours and hours, sometimes even days, I have traversed a forest-bounded road without seeing a blossom gay enough to attract admiration; far oftener I have stopped to pluck a gorgeous fruit. A vast amount of tropical vegetation has small inconspicuous flowers of a more or less green colour, so that when they do occur the eye fails to detect them readily. The fresh green, the rich pink, and even scarlet, of the opening leaves are beautiful beyond description, and the autumn-tinted foliage never ceases through all the seasons; and with so much colour one is quite content to forget the absence of flowers.

"On the passing traveller, therefore, the vegetation at the lower elevations leaves the impression of a tangled heterogeneous mass of foliage of every shape and shade mingled together in such unutterable confusion that not one single plant stands out in anything like its own individuality on his mind."—(*Wanderings in the Eastern Archipelago*, 1885.)

Another contrast has been pointed out by several botanists, that of the relative poverty of the insular compared to the continental floras. But this question is disputed, and the want of sufficient observations does not allow us yet to decide it. Nevertheless, it is certain that the large islands, such as Great Britain, Sicily, Cuba, and Ceylon, have types of vegetation entirely analogous to those of the neighbouring continents; and similarly the Faröe Islands and Spitzbergen have as many species in proportion as the larger countries lying at an equal distance from the pole. The archipelago of Cape Verde, the Canaries, Madeira, and the Azores have, on the contrary, from three to five hundred species less than are found on the same continental extent. Mauritius and Réunion have also a relatively small number of indigenous plants; and it is quite natural to think, with M. de Candolle, that the poverty of these islands proceeds in great part from their long isolation in the open sea.

To the reports on the scientific results of the voyage of the *Challenger* (1873-6), Mr. W. B. Hemsley contributes a valuable paper on the dispersal of plants by oceanic currents and by birds. Descriptions are given of drift-seeds and seed-vessels, and of seeds and fruits from the crops of birds, collected by Mr. Moseley, Dr. Guppy, and others, to which is prefaced an historical *résumé* of the subject. We have, in fact, an epitome of all that has been written upon the subject up to the present time. The evidence Mr. Hemsley brings forward of the potency of these agencies in plant-dispersion is irresistible, and effectively overthrows the opinion so frequently expressed by Alphonse de Candolle—an opinion founded in great part upon the capacity of seeds to retain vitality when immersed in sea-water, as determined by experiment—that oceanic currents have played, and play, an unimportant part in plant-diffusion. The views of the two botanists are placed in striking contrast by a comparison of the list of species certainly or probably dispersed by ocean currents given by each: De Candolle's contains about two dozen, Hemsley's over a hundred. Mr. Hemsley guards himself against being supposed to regard the sea as the principal agent, or indeed of anything more than a subordinate agent in bringing about the present distribution of plants, "for it is manifest that the action of currents and birds of passage are insufficient to account

for certain elements in the vegetation of many islands." But at the same time he goes so far as to maintain that the littoral flora owes its present characteristics to the fact that the seeds of the plants composing it are capable of withstanding long immersion in sea-water, and are thus suited for oceanic transport. That the present general diffusion of a large proportion of the plants inhabiting the tidal forests and sandy and muddy sea-shores of the tropics is in a great measure due to oceanic currents is, in his opinion, quite certain from the evidence; a view from which few, we imagine, will be inclined to dissent. In illustration of this subject he gives (taking a small selection of flowering-plants whose seeds are transported by oceanic currents and by birds) the following picture of the gradual invasion of an island by herbs, shrubs, and trees. "The seeds of many almost ubiquitous sand-binding grasses may be reckoned among those which are cast ashore in a vital condition, and we assume that these grasses are amongst the first flowering plants to obtain a footing. Other herbaceous plants met with in the earliest stage of such an insular flora are *Portulaca, Sesuvium, Canavalia obtusifolia,* and *Ipomœa biloba* (*I. pes-capræ*); all of which seem to possess an unlimited power of colonisation. Moreover, they provide the conditions necessary for other plants to be able to establish themselves. Among the early shrubby occupants, *Suriana maritima, Pemphis acidula, Scævola Kœnigii,* and *Tournefortia argentea* are prominent, being found on the most remote islets of the Pacific and Indian Oceans within the tropical and sub-tropical zones. Where there are muddy shores, there the various mangroves (*Rhizophora, Bruguiera, Avicennia, Vitex,* &c.) take possession. Among the first real trees are *Heritiera littoralis, Hibiscus tiliaceus,* and *Barringtonia speciosa,* together with screw-pines. After this nucleus of a flora has been formed, it is comparatively easy for other arrivals to establish themselves; and every addition in a measure helps to provide the conditions for a still more varied vegetation." And he concludes:—"It may be safely assumed, therefore, that if oceanic currents and birds have not been the means of dispersing a large number of species of plants, and it is not certain that they have not, they are certainly the most important agents in stocking islands, for without their action the numerous remote coral islands, at least, would still be utterly devoid of phanerogamic vegetation, and consequently uninhabitable."

As a concrete illustration of the influence of these agencies in stocking islands, an analysis of the indigenous vegetation of the Bermudas is given, which shows that 45 species are chiefly littoral plants, the seeds having been probably conveyed to the island by oceanic currents; 38 are marsh plants, with small seeds, possibly conveyed to the island in mud adhering to birds, though many may have reached in vegetable drift; 13 are plants with more or less fleshy fruits, and probably were carried by frugivorous birds, leaving a very small number of species introduced, probably indirectly, by man.—*Nature.*

The principal fact in the distribution of plants over the surface of the globe is the increasing richness of the floras in the direction from the poles to the equator. Thus the island of Spitzbergen, the best explored of the countries of the frigid zone, has only 90 species, while on an equal surface Silesia has 1300, Switzerland 2400, and Sicily, much less in extent, possesses 2650. It is true that in many countries of the tropical zone exceptions have been ascertained to this law of the augmentation of species towards the equator, but all these exceptions may be easily explained by soil and local climates. The Sahara has certainly a flora much less rich in proportion than that of southern Europe; but then what a difference there is between these two regions in regard to the physical configuration of the surface!

If Egypt has only a thousand plants, while Great Britain, situated much more to the north, presents on an equal extent 1480, it is because the valley of the Nile is only a narrow alluvial land, bounded on one side by sand and on the other by rocks destitute of moisture. Without being deceived by the relative poverty of the Egyptian vegetation, even the Greeks asserted that the number of plants increased more and more towards the south; they even added this fanciful detail, that in the burning countries of the south the ground sank under the enormous weight of the trees that it supported.

As regards islands of coralline or volcanic formation situated at great distances from the continents, the lack of easy communication must necessarily have prevented these comparatively recent lands from being peopled, except by a small number of species whose seeds resist the action of salt water, or may be easily transported by winds. On Easter Island, lost amid the waters of the South Pacific Ocean, Hooker failed to discover more than eighteen flowering plants, whereas in the neighbourhood of London as many as 400 may be met in the space of a square mile. Even on the Roman Colosseum the recent works of clearance have revealed amid the ruins no less than 420 vegetable species, comprising 66 families and 250 genera. This surprising statement is made on the authority of Richard Deakin in his "Flora of the Colosseum of Rome" (1875).

In Chatham Island, of the Galapagos Archipelago, Darwin found only ten species, of such stunted growth that they might seem to have belonged rather to the flora of the polar than of the equatorial regions. It has been also ascertained that owing to the greater humidity of these islands the proportion of their dicotyledonous plants is far less than on the continents. Each of the islands in the Galapagos group has its special flora, some species being found only on one or two islands, while the range of others is more extensive. Of the 332 species hitherto discovered in the archipelago, as many as 174 are peculiar to it, and 158, or less than half, have been introduced from other regions, such as Peru, Chili, Mexico, and probably also the West Indies, at a time when the Isthmus of Panama was still submerged, allowing free communication between the Atlantic and Pacific equatorial waters.

Unger has proposed to divide the surface of the earth into different zones of vegetation, succeeding each other symmetrically from the two poles to the equator. The northern polar zone, to which a still unknown southern pole corresponds, comprehends the icy archipelago of America, Greenland, Spitzbergen, and northern Siberia. Forests are entirely wanting there; thus, as Linnæus says, the lichens, "the lowest of the vegetables, cover the last land." To the south of this extends the Arctic zone, where the first trees and the first crops show themselves. Next comes the sub-arctic zone of British North America, Iceland, and northern Russia, characterized by peat-bogs, tundras, and forests of pines, fir, larch, and birch-trees. The cold temperate zone, the southern limit of which is found near the 45th degree of latitude, also presents regions of peat-moss and forests, but it is also the especial country for meadows, and its woods are composed of the most varied species. In the warm temperate zone the meadows become rarer, while the arborescent species gain still more in splendour and brilliancy. The palm-trees and bananas make their appearance in the sub-tropical zone; but it is in the tropics and at the equator that vegetation is developed in all its marvellous richness. To the south of the equinoctial line the floras succeed each other in inverse order to the Antarctic pole. But, as we can understand, these divisions are for the most part arbitrary, and in nature the transitions are effected from zone to zone in a

generally imperceptible manner. It is a remarkable fact that one of the most clearly defined zones is exactly cut in two by a vast maritime basin. This is the vegetable zone which surrounds the Mediterranean from the Gulf of Lyons to the delta of the Nile. The Mediterranean flora is thus a narrow circular band developed over a linear extent of more than 5000 miles.

Owing to the diversities of the earth's surface, the differences of temperature and climate, owing also to those secular displacements of continents which result in an equal displacing of floras, all countries are distinguished one from the other by a characteristic vegetation. Scandinavia has its forests of coniferous trees, England has its oaks and its meadows, the north of Germany has its lime-trees, Russia its birch-trees, France its elms and beeches. We cannot think of even the Vosges or the Black Forest without recollecting those long slopes covered with firs; and when we dream of the Alps, we always see them in our memory with their clumps of walnut or chestnut-trees, their forests of larches, their rhododendrons, and their gentians. In the same way we cannot imagine the beautiful

Fig. 167.—The Mediterranean Flora.

country of Italy without olive-trees, cypresses, and maritime pines. The terrible monotony of the Sahara is relieved by fresh oases of date-trees, and towards the southern extremity of the continent, at the Cape of Good Hope, the harsh contours of the hills and mountains are enlivened by their carpet of heaths and many-coloured flowers. The United States have their trees with marvellous autumn tints, where all shades are found at the same time, from the most dazzling purple to the darkest green. The contrast is great between these forests with varied colours and the uniform extent of the prairies on the west, or the deserts of New Mexico scattered over with cactuses. In South America the forests of Araucarias, of the mountains of Chili, and the Brazilian plateau, do not present a less striking contrast with the pampas and their vegetation, so rich in leguminous plants. At the other extremity of the world the Australian flora contrasts with that of the whole world by the antique appearance of its eucalyptus and its *Casuarinaceæ*, dating, perhaps, from the Jurassic epoch. The species of New Zealand are distinguished also by their general aspect from that of all the continents. Nowhere

else do we see so great a proportion of trees and shrubs compared with annual plants; nowhere do the cryptogams present such a variety of forms. Meadows are wanting, but the ferns grow in immense forests, as at the epoch of the coal formation. The succession of terrestrial ages which the geologists seek in the fossiliferous strata, and which they estimate at millions of centuries, the botanists may see in summary at the present epoch by traversing the surface of the globe. The floras of the past periods, stored in the strata of western Europe as in an immense charnel-house, still live, more or less modified, in various parts of the globe.

Virgin forests, where man has scarcely ever penetrated, save to make a few paths, are among the grandest spectacles of nature. Those of cold countries, composed for the most part of coniferæ with straight trunks and dark foliage, have something solemn and august in their appearance. The mighty shafts of the trees are planted regularly like the pillars of an immense edifice, and in the distance appear in mysterious avenues. The branches, widely spread and laden with greyish moss and lichens, only allow a diffused light to pass through their boughs, spreading as they do symmetrically under the vault of thick verdure. A few knotted roots here and there peep from the ground, which is covered with fallen leaves and sown with modest plants, some clustering at the foot of the trunks, others grouped in masses in the open spaces. Nothing from without penetrates into this retired world, excepting it be a ray of sunlight darting like an arrow between two boughs, or the sighing of the wind among the branches.

The great tropical forests have quite another character, and strike us especially by their magnificence, the luxuriance of their vegetation, and the variety of their species. It is not so majestic and regular as a forest of firs or larches; it is a chaos of verdure, an accumulation of interlacing foliage, where the eye vainly seeks to distinguish the innumerable vegetable forms. Above the large tufted tree-tops others are perceived, and palm-trees rise united to each other by an inextricable network of lianas; broken boughs suspended by almost invisible cordage swing in space; the pandanus spring like rockets of verdure from the confusion of branches and leaves of every variety, which are disposed in plumes, fans, bouquets, and garlands; orchids expand their strange flowers in the air; trees which have fallen from age disappear under the mass of flowers, and the greater part of those still upright are themselves surrounded, as with a new bark, by spiral stems of parasites with elegant foliage. While in the forests of the north all the trees resemble each other and yet grow isolated, like the independent citizens of a free people, the innumerable species of the tropical forests, so different from each other in dimension, form, and colour, seem to be mingled in one and the same mass of vegetation; the tree has, so to speak, lost its individuality in the life of the whole. An oak of the temperate zone, spreading its boughs with their rugged bark, plunging its roots into the crevices of the soil, and strewing the earth with its withered leaves, always seems to be an independent being, even when surrounded by other oaks like it. But the finest trees of a virgin forest of South America are not independent; twisted round each other, knotted in all directions by cordages of creepers, half hid by the parasites which strangle them and drain their sap, they are lost in the immense mass of vegetation which covers the entire country.

It is from the even surface of the sea or of a great river that one ought to see the tropical forest, especially when it clothes the sides of an elevated hill from the summit to the base. Under this undulating mass we can hardly imagine the soil that supports it; we might think that the entire forest was rooted in the waters

and floated like an enormous pyramidal plant, 200 yards high. Where the hill presents a rapid declivity, great masses of branches, creepers, and their flowers stretch from tree-top to tree-top like the sheets of a cataract. It is a Niagara of verdure. A moist atmosphere, laden with the mingled scents of the plants, escapes from the forest and spreads itself afar; in foggy weather travellers have recognized, at 100 miles out at sea, their proximity to the coasts of Columbia by the perfumes diffused abroad.

Of all these marvellously rich tropical vegetations, the most varied is that of the basin of the Amazon, as indeed the geographical situation of the country is sufficient to show beforehand, for nowhere else can we find rich alluvial soil, abundance of rain, and power of solar rays so admirably united over such a vast extent. Over a space of many thousands of miles from north to south and from east to west, the plains of the Amazon are nothing but a limitless forest, interrupted only by the wide channels of the river and its tributaries, and marshes and lagunes on their banks, and here and there by glades with high grass where a few scattered trees appear. The botanist stands confounded before the immense variety of plants which present themselves to him; while in the river itself he already sees a series of interlacing trunks and branches still garnished with their leaves, which the current carries away like a kind of floating forest. On the marshy soil of the shore reeds are crowded together, which advance in promontories. On the bank, properly so called, the alluvium deposited each year has its particular vegetation—higher, more tufted, and more entangled with creepers, the more ancient the soil is on which it grows. Beyond this first rampart of new trees, which in many places hides the real forest, the virgin solitude of the great woods commences, where the flora of the Amazon is seen in all its beauty and all its majesty at the same time, owing to the prodigious number of plants that compose it. The most varied types, climbing herbs and gigantic trunks, are mingled together; light creepers suspended to the branches connect in one network the boughs of the entire forest. This is a wonderful picture, which ought to be contemplated in free wild nature, either on the shores of some lagune, where the enormous leaves and delicate rosy flowers of the *Victoria regia* display themselves, or else on the surface of a tortuous stream, all festooned with garlands of interlacing plants, which float beside the canoe of the traveller. In no country in the world are strength, loveliness and grandeur, with at the same time great beauty of detail, combined in so happy a manner; it is the triumph of living nature. The forest is at the same time grand and joyous, and has nothing of the melancholy of the woods of the temperate zone.

If all the plants of the world are not found in the vast *selvas* of the Amazon, at least all the genera, even those which are completely missing, still have their representatives. Thus the family of *Rosaceæ*, which gives us the charming eglantine of our hedges and the beautiful garden roses, the greater number of our fruit-trees, the pear and the apple, the peach, cherry, medlar, almond, and many others, hardly exists under the tropics; but these plants are replaced by another great family, that of the myrtles, which produces the guava, the pitanga, and a great many savoury fruits, whose names are scarcely, if at all, known beyond the tropical regions. Thus each zone has its special family of fruit-trees. In the same way the humble cereals of the north, the grains of which serve as the chief food for man, have equivalents in the neighbourhood of the equator in the great family of the palms, of which so great a number of species live on the banks of the Amazon and its affluents. Each of these rivers has its characteristic species of

palm-trees, giving a new aspect to its forests and the villages on its banks. Even on the principal river the varieties succeed each other several times, from the embouchure to the confluence of the Solimôes with the Rio Negro, and higher up as far as the mountains of Peru. The species of this tree, which support the natives with their fruit and furnish them at the same time with refreshing water, with tissue, and with building materials, are still more numerous than the cereals of the northern countries. And yet the Amazonian regions are scarcely known even now save in the immediate neighbourhood of the river-banks, and each new exploration of botanists there will reveal the existence of new vegetable treasures.

CHAPTER LV.

DISTRIBUTION OF VEGETATION ON THE SLOPES OF MOUNTAINS.—MINGLING OF THE DIFFERENT FLORAS.—UPPER LIMITS OF THE PLANTS IN VARIOUS PARTS OF THE WORLD.—IRREGULARITIES IN THE VERTICAL DISTRIBUTION OF PLANTS.

IN consequence of the gradual decrease of temperature on the sides of mountains, zones of vegetation, analogous to those which succeed each other from the equator to the pole over the surface of the globe, are situated one above the other from the base to the summit of mountains. By the flora, as by the climate, we might think we were proceeding in the direction of the polar regions, in proportion as we ascend the sides of a peak at a higher altitude above the plains; but the intervals of climate that it would take days to cross in travelling towards the pole, are traversed in a few minutes of ascent, since in the mountains a height from 175 to 260 yards corresponds on an average to one degree of latitude. At the foot of the plateau which bears the Cayambe, in the equatorial Andes, the vegetation is that of the torrid zone; at the snowy summit of this volcano, which is intersected by the very line of the equator, we find plants recalling those of Greenland; but to whatever height we ascend, we always find living organisms. Above the snow itself the cellules of the *Protococcus* are grouped and live, as in the deepest seas the sounding-lead still discovers diatoms in infinite myriads.

The limit which separates the flora of the mountain from that of the lower plains is not always very distinct, and we must often traverse vast debateable regions before knowing by the aspect of the surrounding plants what zone of vegetation we have under our eyes. In the same way it is very difficult to distinguish, on the slope of a mountain-chain, the various floras, one above the other, because certain plants are common to two zones at once, and some, from various physical causes and changes, descend below or mount above the normal region of their abode. It is thus that on the sides of the volcano of Chiriqui, Moritz Wagner found meadows and evergreen oaks beside euterpe-palms and bignonias. In the same way, too, in the Columbian state of Santander, the banana and the sugarcane flourish excellently at the height of 9000 feet, in the midst of the region of oaks and birches. There is, therefore, not only superposition, but also an intermingling of climates and forests. In the Cordillera of Valdivia this mixture of floras is such, that trees of the plain mount almost to the lower limit of perpetual snow, owing to the extreme abundance of rain, and to the equality of the climate.

The mountains where the limits between the zones are more clearly defined are, as we can understand, those whose slopes are cut in abrupt escarpments. A

precipitous rock some hundred yards high is most frequently a visible frontier between two floras; one may see a magnificent example of this at the fall of Tequendama in Columbia, where the water plunges from the zone of apple-trees and rye, to fall into that of the palms of the Mauritius. Similarly, a sudden change in the physical conditions of the place can define clearly two zones of vegetation. In Vallouise, not far from the foot of the Grand Pelvoux, we observe, on the southern slope of the mountain of Echanda, a line of demarcation, straight as if drawn by a cord, between the zone of shrubs and that of the short grass of the pasturages; this is because the lower part of the Echanda is sheltered by a promontory, above which the cold wind descending from the glaciers passes freely. On the sides of the volcano of Riñihue, in Chili, M. Frick has remarked also that the line indicating the limit of the trees is perfectly horizontal.

The phenomena which contribute each in its way to render undecided the limits of the superposed floras vary in their action according to the innumerable diversities which the slopes present. Every difference in the slope, the exposure, the nature or the hardness of the soil, produces a corresponding difference in the width of the zone, where the plant is freely developed. In one valley well sheltered from the cold winds, open to the warm breeze from the plain, and abundantly watered by rains, the plants of lower countries often ascend to heights several hundreds or even thousands of yards above their native soil; in other places, on the contrary, the plants of the elevated zone favoured by the cold winds which are ingulfed in the gorges, descend to a great depth below the imaginary limit of their abode. In the same way species which live in the neighbourhood of the snows sometimes advance with erratic blocks on the surface of the glaciers and then are driven with their terminal moraine as far as the lower plains; at other times they fall from the top of the mountains with fragments of stone, and in passing at the foot of an escarpment we are suddenly surprised to see a foreign colony growing and thriving in the midst of plants of another climate. Even the avalanches of snow which slowly melt in the meadows beneath the passes from which they have fallen leave traces of particular species as signs of their sojourn there. Two laws act in contrary directions on the sides of mountains, one which tends to cause the lower plants to ascend towards the summits, and the other which tends to make those of the high peaks descend, and in consequence of this incessant conflict the limits of the zones are constantly displaced with the oscillation of the climates.

Since the time of Humboldt, Chimborazo and Popocatepetl have often been taken as types of mountains with superposed stages of vegetation; still these two mountains can be taken only as representatives of the temperate regions in which they stand, for they are erected upon plateaux, and in order to find a tropical flora we must go to a great distance from their bases. The Orizaba of Mexico, whose regular cone is so well seen from the sea, and the Sierra Nevada of Sta. Marta, which towers 19,500 feet above the shores of New Grenada, are the most striking examples of this arrangement of climates and floras in stages. From their base we may vaguely distinguish on the slopes a *résumé* of the vegetation of the globe, from the cocoa-nut palms which bend over the shore, to the Alpine plants the verdure of which is recognised from a distance by the contrast it forms with the whiteness of the snows. On the sides of the volcano of Chiriqui, a mountain of less height, which also stands on the shores of the Caribbean Sea, Moritz Wagner was able precisely to measure the height of the successive stages. That of the palm-trees and the *Musaceæ* rises to about 2000 feet; the tree-ferns and orchids show themselves from 2000 to 4000 feet; above them the rosaceous family

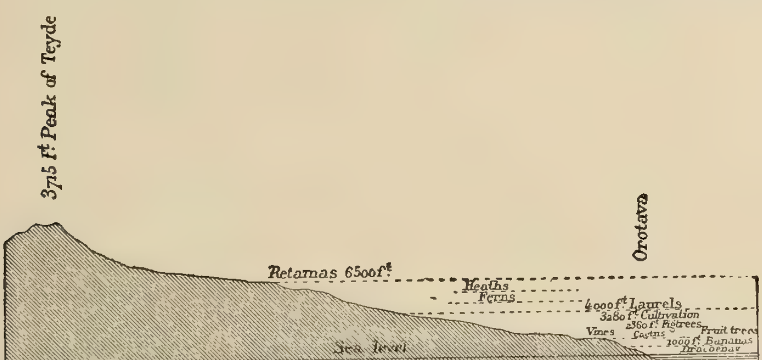
grows to 5000 feet; and higher still, from 5000 to 10,000 feet extends the region of the oak and birch. In the island of Java, the isolated volcanoes which rise above the plains of exuberant tropical vegetation are also admirably situated for enabling us to study on their sides the natural and cultivated floras and the crops in their different stages, from the base to the summit of the mountains.

Isolated mountains which are bathed in an atmosphere where the meteorological phenomena occur with great regularity, present in consequence a normal series of

Fig. 168.—Botanical Map of Java.

floras in stages from their summit to their base. Among the mountains which may be considered as types of the regular distribution of the zones of vegetation, we may cite the peak of Teyde, the central mountain of the group of the Canaries. On descending the height of this volcano in the direction of Orotava we at first see

Fig. 169.—Stages of Vegetation on the Flanks of the Peak of Teyde, Isle of Teneriffe.

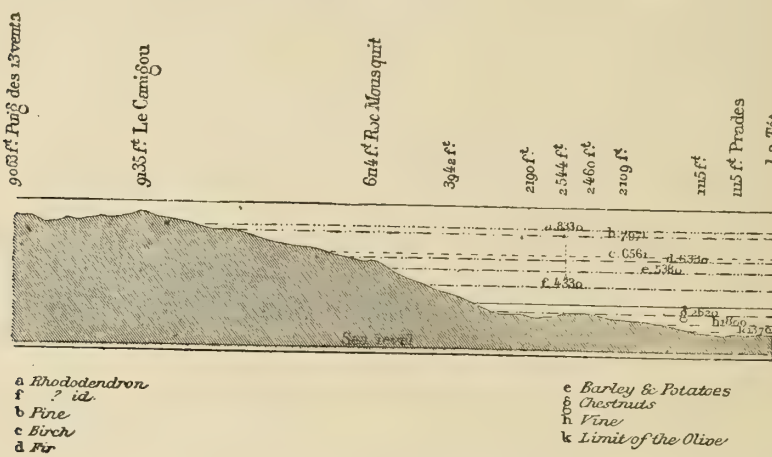


nothing but *retamas*, always *retamas*, a kind of greyish genista, which delights in a soil of ashes and cinders. All at once a new plant appears, a heath, and soon we are surrounded with heaths on all sides, and the *retamas* have completely disappeared. One solitary old pine marks the clearly defined line of demarcation which separates on the mountain-side the zone of plants of sombre tints from that of verdant plants. In proportion as we descend the heaths are higher and more crowded together, then they are mixed with ferns; towards 3800 feet of altitude

the laurels rise here and there in the middle of the thicker brushwood, and the volcanic soil is covered with grass. Below 3300 feet the crops begin, lupins, corn, and a few vegetables, while nettles are seen to grow at the edge of the path. At 2500 feet the first fig-tree is found, and then we enter the region of vines, cactuses, and fruit-trees; finally, at 1000 feet we enter the subtropical zone, indicated by the bananas and dracænas.

Among the high mountains of France the Canigou is that which rises most proudly above the plain, and on its sides, which are entirely visible from the open sea, M. Aimé Massot and other botanists have been able to measure with great exactitude the separate zones of vegetation. The olive-trees, which cover the plains of the Têt and Tech, grow also on the offshoots of the mountain at a height of 1300 feet; the vine rises higher, but at 1800 feet it disappears in its turn; above 2500 feet the chestnut ceases to grow. The last fields cultivated are rye and potatoes, which do not pass 3300 feet, a height at which the beech, the pine, the fir, and the birch already suffer from the wind and the cold of winter. The fir stops at 6400 feet, the birch does not venture beyond 6500 feet, but the hardier pine scales

Fig. 170.—Stages of Vegetation on the Flanks of Canigou.

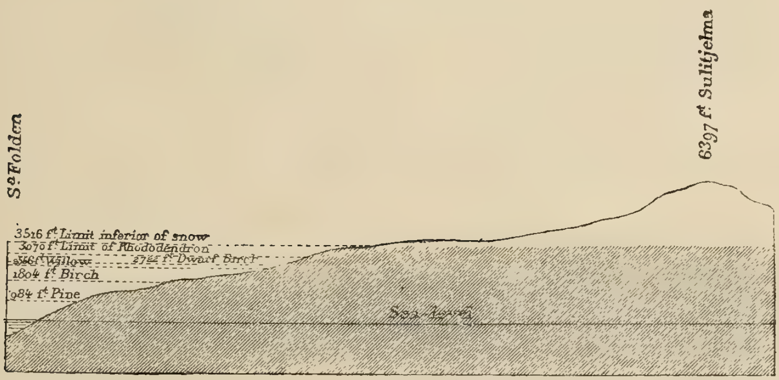


the rocks to the altitude of 7000 feet, not far from the summit. Above this the vegetation is composed only of Alpine or polar species. The rhododendron, the first tufts of which showed themselves at 4000 feet, extends to a height of 8000 feet. As to the juniper, it climbs up the mountain, half hiding its branches in the soil, to the terminal point 9000 feet high, which is covered with snow during three months of the year.

The stages of vegetation have been studied with care on the slopes of many other mountains of temperate Europe, especially on the sides of the Ventoux, by M. Charles Martins; but it is in the Alps above all that the most celebrated botanists of our century have made their comparative researches on the floras of the various altitudes. The limits of these floras vary, so far as we can understand, according to the form, exposure, and height of the mountains, the nature of the rocks, the moisture of the soil, the abundance of snow, and the meteorical conditions of the surrounding atmosphere. It is, therefore, impossible to give the precise figures on the whole of the Alpine masses, and the averages obtained by savants have only a very general value. Without taking account of the upper limit of cultivation, which varies singularly in the high valleys in proportion to the

industry, intelligence, and social condition of the inhabitants, we may say that the vegetation of the plain hardly exceeds 3000 feet; above this height the slopes where man has not violently interfered to change the productions of the soil, are naturally covered with vast forests. Still the great trees gradually diminish in height, in proportion as we rise into a zone where the air is rarer and colder; their wood becomes harder and more knotted, and the hardy kinds, which venture not far from the region of the snows, end by creeping on the ground, as if to seek shelter between the stones. To the north of Switzerland the beech does not exceed the height of 4000 feet, and the spruce fir stops at 6000 feet. In the group of Monte Rosa the same forest growth, which approaches most nearly to the zone of perpetual snow, ascends as far as 6200 feet on the northern slope, while on the opposite side, the larch, still hardier, attains its upper limit at 7200 feet. Higher still, we only see the fantastically twisted trunks of a few *mugho* pines, rhododendrons, willow-herbs, and juniper-trees; then all vegetation becomes more stunted, and is attached to the ground in order to escape the icy winds, and to allow of its being covered in winter with a protecting layer of snow. Up to the very edges of the glaciers, and the white surface of the snows, the phanerogamous plants will grow even at 11,500

Fig. 171.—Stages of Vegetation on Sulitjelma.



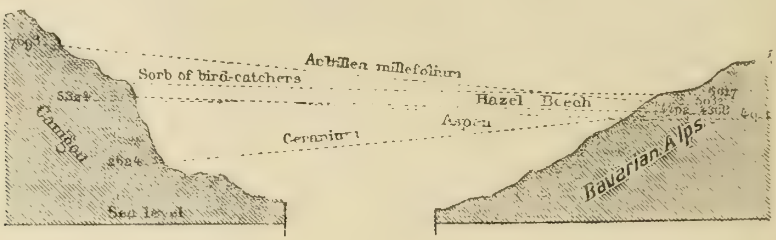
feet high; we see androsaces, gentians, saxifrages, and the charming thrift with its pink flowers gracefully placed on a cushion of green moss. In the middle of summer freshly fallen flakes will sometimes half cover these tiny plants, when we might think the snow was veined with blood. Even the highest rocks are covered here and there with lichens resembling rust, and often the very snows themselves are shaded in red, green, or dull yellow, by a flora of rudimentary cryptogams.

The distribution of the vegetable species is effected in an analogous manner on the sides of other mountain-chains, situated to the north of the Alps, the Vosges, the Erzgebirge, the Sudetes, and the Kjölen mountains; only, as we can see on the slopes of Sulitjelma, which rises in Norway under the 68th degree of latitude, the series of stages of vegetation becomes less and less rich in proportion as we advance towards the north, because of the gradual diminution of the mean temperature and the relatively inconsiderable height to that at which perpetual snow begins. It is to be remarked, also, that the different species are far from succeeding each other in the same order on the slope of the mountains. The upper limits of plants present the most striking irregularities in this respect, and intersect each other variously instead of remaining parallel to one another, as we might expect at first.

Thus the aspen rises to a less height than the beech in the Bavarian Alps, and the contrary occurs on the sides of the Canigou; on the other hand, on this same mountain, the aspen leaves the hazelnut far behind, while in Bavaria it is distanced by the hazelnut by about 225 feet. We have attempted to make these remarkable phenomena more intelligible by means of a diagram.

The polar limits of the various vegetable species do not succeed each other exactly in the same order, any more than the upper limits of similar plants on the slopes of mountains. These differences in the distribution of corresponding floras are connected with the multitude of causes which hinder the propagation of plants over a more extended area. A plant may be arrested on one side by the cold of winter, on another by fogs, drought, moisture, or the neighbourhood of snows. Each region of the world having its special climate, also presents special conditions

Fig. 172.—Comparative Height of different species of Plants on Canigou and in the Bavarian Alps.



for the development of life. Even on the opposite slopes of a single mountain the stages of vegetation present remarkable contrasts. Thus the mountain-pine (*Pinus uncinata*) rises nearly 600 feet higher on the southern slopes of Mount Ventoux than on the opposite side. On the other hand, the evergreen oak mounts to nearly 2000 feet on the northern side, and only to 1800 on the side fully exposed to the midday sun. We observe, too, that each declivity has its special growths; to the south it is the olive-tree, to the north the walnut and firs. In the Alps of Monte Viso and the Col de Tende it is seldom that we fail to observe a rhythmical alternation between the forests on sides differently exposed: larches cover the escarpments turned towards the south, while firs prefer shady valleys looking towards the north. On the mountains of the tropical zone the contrast is more striking still, since on one side impenetrable forests extend, and the other side has only herbaceous plants for its vegetation. Humboldt observed this contrast on the sides of the Duida, which commands the bifurcation of the Orinoco, and it can also be confirmed on most of the mountains of the Sierra Nevada of Santa Marta.

CHAPTER LVI.

UNCONNECTED SPECIES.—DISPLACEMENT OF AREAS IN CONSEQUENCE OF GEOLOGICAL CHANGES.—PLANTS OF GREAT BRITAIN.—NATURALIZATION.—INCESSANT MODIFICATION OF FLORAS.

ONE of the most interesting phenomena of the terrestrial flora is the coexistence of the same plants in two regions separated from each other by vast spaces, where the transport of seeds would not have been possible if nature had not employed other means than those which she employs in the present period. It is certainly difficult in the present state of science to render an exact account of this division of the areas of plants; but one cannot study it too carefully or give too great importance to it, for besides the stratified rocks and fossils, the flowers which spread over the ground recount in their silent language the history of past ages.

Gmelin, and since his time a number of other botanists, ascertained that the vegetation of the mountains of Switzerland does not only resemble the flora of polar regions by the general physiognomy of its plants, but that it also comprehends species perfectly identical with the plants of Spitzbergen, Greenland, and Arctic America. On the terminal cone of the Faulhorn M. Charles Martins has gathered 132 phanerogams, 40 of which are found again in Lapland, and eight in Spitzbergen. In the same way the "Jardin," which stands isolated in the midst of the glacier of Talèfre, resembles by its scanty flora a polar country much more than a rock among mountains of the temperate zone. In this little ice-girt world, which botanists have lovingly studied to the very farthest corner, 128 species of plants live, but only 87 phanerogams; of this number 50 belong also to the Faulhorn, 24 to Lapland, and 5 to Spitzbergen. Observations made on other elevated points of the Alps, at the Grands Mulets, and in the pass of St. Theodule, have given analogous results. On the White Mountains of New Hampshire we also find the same species as those of Labrador, many of which belong equally to the mountain flora of the Alps and the Pyrenees. Finally, the Atlas and Abyssinian mountains, the peak of the Cameroons, the volcanoes of Java, the chains of Brazil and the Andes, and even the rocky escarpments of Tierra del Fuego, have among their species some European plants. Enormous distances, from 600 to 6000 miles, separate these divided areas of mountains to the south, and plains to the north, and we cannot believe that birds or atmospheric currents could have carried the species from one region to the other, for the naturalization of species is most difficult in cold countries, and most of these far-scattered plants have neither berries such as the birds seek for, nor winged seeds such as are carried by the wind.

The same difficulties present themselves when it is necessary to explain how a

great number of fresh-water species live in rivers and lakes deprived of all communication with one another. These are plants whose heavy seeds cannot be transported by the air, and which the sea-water would destroy in time; nevertheless, these plants have been able to penetrate into almost all lacustrine and fluviatile basins, where the temperature suits them. They are seen in islands as well as in continents: they grow on both sides of wide seas, and in the waters which bathe the opposite flanks of high mountain-chains, and by a remarkable coincidence it is precisely these aquatic species, with necessarily limited requirements, which are found most frequently alike in the different countries of the earth. Respecting these water plants, just as regarding those of the mountains, botanists ask how they have been able to establish themselves at the same time in the cold or temperate regions of the two hemispheres at the opposite extremities of continents, since the torrid zone, which separates the areas of habitation by a distance of several thousands of miles, forms an insurmountable barrier between them. Thus even at the two antipodes, in New Zealand and in the seas of western Europe, Hooker has recognized 25 identical species of algæ. The genus *Spartina* presents the most singular contrasts in this respect. One species, *Spartina stricta,* grows in the United States and in Europe on the shores of the Atlantic, and is found at Cayenne, at Venice, and at the Cape of Good Hope. Another species, the *alterniflora,* found alike on the coasts of America, in the United States, and in Cayenne, only shows itself in France at one spot, the mouths of the Adour, and in England on the shores of Southampton Water. Finally, the species called *juncea,* which flourishes in Georgia and in Massachusetts, only appears in the Old World at Fréjus, near the embouchure of the Argens.

It is true that these last-named plants, living always in the sand and alluvial lands of the sea-coast, might easily have been transported by vessels with the ballast and merchandise from one shore of the ocean to the other, and have propagated themselves after having remained for a time in sea-water. M. Godron has seen the seeds of grasses germinate after immersion during a winter in a salt pool. Darwin and Martins have also proved by direct experiments that certain seeds can preserve their power of germination after having floated on the sea during 28, and even 137, days. They think that a tenth of the plants can thus propagate themselves spontaneously along the shores. Perhaps even the *Eriocaulon septangulare,* an American fresh-water plant, which flourishes also on the Scotch island of Skye and the Irish district of Connemara, has been carried from Canada by the Gulf-stream. It is known what a marvellous vitality certain seeds possess. Robert Brown caused the seeds of *Nelumbium speciosum,* deposited in an herbarium for 150 years, to germinate. Perhaps, too, the various seeds contained in the Egyptian tombs could, as many botanists assert, have preserved their latent life for thirty and forty centuries. Many geologists, indeed, believe that the rare plants suddenly springing up above the remains of ancient fossiliferous strata originate really from seeds that have been buried during a whole series of terrestrial revolutions.

However it may be, such phenomena occur in too small a number of plants for us to be able to explain in this way how so many vegetable species having several habitats can flourish at a distance from the sea and all highways of commerce, either in lakes and streams, or on the sides of snowy mountains. We can only imagine two alternatives in the case of these plants,—either their germs have been developed spontaneously on all the spots where the separate colonies are now found, and each mountain summit, each fluvial and lacustrine basin has become an independent centre of vegetable generation; or else the now scattered colonies

were formerly connected with one another, and have been gradually separated, or even displaced, in consequence of the changes of the surface or climates of the earth. The humble Alpine flowers, hiding in the snows and in the crevices of rocks, would thus relate the great revolutions of the globe.

In fact, during the earlier geological periods the mean temperature underwent frequent changes, as the fossils in the strata of the earth prove. In the same country the climate has been alternately hot, temperate, and cold; then it has become heated again, and consequently the living organisms, plants, and animals have been incessantly displaced on the surface of the earth. Towards the end of the Tertiary epoch, when the regions which have now become the continents of Europe and North America still enjoyed a high temperature, the vegetation must have had a much more southerly character on the whole than in our days: in the same way the scattered lands which surround the Arctic pole had doubtless a uniform flora, composed of plants analogous to those of our temperate zone. But the climate gradually changed, and the cold which was to bring on the Glacial period began to reign over the northern hemisphere. There was a repulse of the species which had advanced too far towards the north and missed the necessary warmth. They beat a retreat before the snow and ice like an army in flight. The plants of the polar zone gained little by little on the temperate zone, those of the temperate zone retreated towards the tropics, and by the gradual encroachments of their colonies even crossed the equator and established themselves on the now scorching plateaux and plains of the torrid zone. During the series of centuries of an unknown length which elapsed during the Glacial epoch of our planet, a certain number of displaced species sought vainly to accommodate themselves in their new countries, and ended by succumbing, whilst other plants, favoured by the climatic conditions, grew without difficulty in the land of their exile, or even enjoyed greater prosperity than in their ancient abodes.

Nevertheless the temperature, changing incessantly like all the phenomena of the universe, entered upon a new phase: to the cold period succeeded an increasing warmth on the surface of the northern hemisphere, and perhaps over the whole earth. The glaciers which filled all the mountain gorges and advanced far into the plains, retreated gradually towards the peaks, leaving in the fields heaps of the earth and débris which they had carried for centuries. To the north the snows of continents and the ice-fields of the sea retreated more and more from the temperate zones, and approached nearer to the poles. Owing to the warmth, plants which the cold had forced to take refuge in the equatorial regions, and had enabled to propagate themselves in both hemispheres, were thus divided into two distinct *corps d'armée*, retiring from each other in proportion as the temperature increased. In the same way the species of the temperate zone gradually encroached on the ground in the direction of the pole, and advancing to the assault of the mountains, took possession of the moraines and ravines abandoned by the glaciers; but in order to conquer the mountains and polar regions, they were obliged to yield the intermediate plains to other plants which had come from the south. An ever-widening space occupied by a new flora interposed itself between the two separated fragments of the ancient flora, and in our days, after the lapse of ages, the European species of the Glacial epoch have no longer any other country than the Arctic lands and the rocks surrounded by snow on the summits of the Alps and Pyrenees. Like those tribes of mountaineers, Basques, Romanshes, and Vaudois, who, to preserve their customs and their nationality, have taken refuge in high valleys, the little vegetable population besieged by the plants of the lower plains

have retired to the snowy heights, where they find a climate which reminds them of the Glacial epoch. Thus all distributions of species which cannot be explained by the present condition of the terrestrial surface may be explained by reference to former conditions.

This is not all: to such important alternations of climate are added also, for the modification of vegetable areas, the numerous changes of form and relief to which the continents have been subjected. When Scandinavia was an insulated country, when a vast sea occupied a great part of the plains of northern Germany and Russia, and a strait allowed the Black Sea, the Caspian, and the Gulf of Obi to communicate with each other, there is no doubt that maritime currents and convoys of floating ice served to transport Arctic species to the sides of European mountains. Later, while the countries of Europe rising out of the Scandinavian sea gradually assumed the contours that they have now, their relief was also modified in various ways; the heights were elevated, and thus basins formerly separated were united; hills worn away by the waters disappeared little by little, and in their destruction a communication was opened between two valleys formerly distinct; lakes were formed, others were dried up, and rivers changed their courses. Thus the soil with the seeds which former vegetations had deposited there was incessantly altered. Why therefore should we be astonished to see the same aquatic plants flourish in so many basins now completely isolated? Communication which does not exist now existed directly or indirectly during previous geological ages, and that is sufficient to explain the coexistence of scattered areas of habitation. However, in following this path it is so easy to allow oneself to be carried away by daring suppositions that it is important to prove established facts very carefully before adopting them. Thus, M. Schmidt having ascertained that the present flora of the coasts of Siberia and China resembles much more that of the Atlantic shores of the United States than that of California and Oregon, concludes from it that Asia and America formerly composed a single continental mass, and then that a part of the centre, after having been gradually submerged in the depths of the Pacific, rose again to re-clothe itself with a second flora entirely different from the first.

The flora of the British Isles is a remarkable example of the changes which have operated during the modern period in the areas of species. With the exception of a single plant of American origin, the *Eriocaulon septangulare*, which is found in a part of the Hebrides, the whole Anglo-Irish vegetation is of continental origin. The great majority of the species have been propagated directly from France, Holland, and Germany, before the English Channel had been opened by the waves. Another flora in the north of quite an arctic character must have been brought from Scandinavia by icebergs laden with débris; finally, the arbutus, and about ten of the plants growing in the mountainous regions of the south-west of Ireland, are only found again on the shores of the Bay of Biscay, in Portugal, in Madeira, and the Azores, and there are strong reasons for admitting with Edward Forbes that they formed part of the flora of a great continent, which has now almost wholly disappeared. Thus the modifications of climate and the oscillations of the soil, without counting the still more important changes introduced by the work of man, have resulted in concentrating parts of three very distinct floras in the relatively narrow space of the British Isles. Besides this, 83 species of foreign origin have been naturalized there during modern centuries by the voluntary or involuntary intervention of man, who is himself one of the great geological forces.

Since the discovery of the New World the two continents, which navigation continually joins together, have mutually enriched their floras by the naturalization of new species. At least 35 plants of North America have acclimatized themselves in Europe, and 172 European species have been propagated on the soil of the United States. America has thus greatly gained in this exchange. Europe has discharged on the New World vegetable populations as well as human populations; and these colonizing plants, invaders like the rude pioneers themselves, have in many spots displaced the native species. In less than a century it is said that the common trefoil of Europe has conquered nearly half the continent, from Louisiana to the Rocky Mountains. In Australia, Van Diemen's Land, and New Zealand, the invasion of the conquering plants is accomplished in perhaps a more rapid manner still; a few years sufficed to change the physiognomy of the vegetation in whole districts. The European colonists, occupied only with agriculture and commerce, would willingly leave to their new country the strange flora whose very aspect astonishes them; but from their fields and gardens plants which have come with them from Great Britain escape, and spreading, take possession of new domains; more rapid in their triumph than the English themselves, they are incessantly driving before them the aboriginal plants. The ancient flora, scarcely modified since distant geological epochs, is greatly changed in less than a century; one might say that these countries, the last representatives of a vanished period, abandon the fashions of the old times to dress themselves in new costumes. Thus the conquering peoples and the colonists are always accompanied by species of plants, invaders like themselves. The Persians and the Greeks, the Crusaders, the Arabs, the Mongols, and the Russians, have carried the plants of their country with them in their wars of invasion, in the same way as English and American pioneers carry theirs into the solitudes of uncultivated lands. In this point of view the history of the plants which have been naturalized without the knowledge of man is to some extent connected with the history of humanity itself.

If there are botanical areas which increase in extent, there are, on the other hand, many others which are gradually restricted or which even disappear: certain plants have not only been driven back like the Maoris of New Zealand or the Red-skins of North America, they have been completely destroyed, and no longer exist, except in herbariums, or else in the state of dormant seeds in the crevices of rocks. Thus Darwin tells us that during a century the island of St. Helena has lost a great number of species. Its flora, composed of 746 phanerogams, almost all of English importation, no longer comprehends more than 52 indigenous species; its ancient forests of different species, which extended over more than 1900 acres, have entirely disappeared, and several species have been utterly annihilated by goats and pigs; others are dangerously threatened, and botanists expect soon to have only the recollection of them. Even in Europe, where colonization has not suddenly changed agriculture and vegetation, plants have certainly ceased to grow in various countries. Thus the water-chestnut (*Trapa natans*) and the dwarf water-lily, which peopled the waters of Switzerland at the epoch of the lake-cities, are no longer to be found in that country. Certain regions of Ireland, where the forest vegetation has been completely destroyed, either by man or by natural causes, still possess, under their incessantly increasing beds of peat-moss, fragments of pines and oaks; in the same way in the Shetland Islands trunks of a fir-tree, *Abies pectinata*, which is now completely wanting in the British Isles, and even in Scandinavia, have been found in the peat.

Besides, the experience of all the foresters and the testimony of history are

amply sufficient to demonstrate that nature requires a continual change, an incessant rotation in the products of the soil. In all countries, if a forest be burned it is immediately replaced by other species; a "re-growth" of new trees springs from the earth instead of the old species, then after a certain number of centuries disappears in its turn to give place to the trees of former times; in the forests of Perche each of these re-growths lasts, on an average, from 290 to 330 years. Even when fire or violent destruction does not suddenly sweep away a forest, the latter does not the less transform itself in the course of centuries. According to M. Paul Laurent, a forest of Europe that in the Middle Ages consisted of beeches is to-day composed of oaks. Similarly, forests of oak, like that of Gerardmer, where Charlemagne went hunting, have been replaced by the fir and pitch-pine; the forest of Haguenau, now a pine-wood, was composed of beeches a century and a half ago. Finally, a number of localities which have formerly received the names of Charmettes, Pinasse, or Pinière, Châtaigneraie, Tremblaie, Boulaie, no longer have the species which have given them the name they bear. In the meadows also, M. Dureau de la Malle says that a rotation, lasting for several years, is established between the graminaceous and leguminous plants. The vegetable populations are constantly changing; the life which germinates from the ground is, like the ground itself, in a state of perpetual transformation.

CHAPTER LVII.

ORIGIN OF LIFE.—SPECIES OF ANIMALS.—MULTITUDE OF ORGANISMS.—CONTRASTS OF LAND AND SEA.

NATURALISTS have not yet distinguished precisely, amid the multitude of incipient organisms, the boundary which separates the plant from the animal. How many dubious forms there are! How many indefinite species difficult to class in one or the other systems of organized beings! Are they vegetables? They grow and are developed like them. Should they be classed among the animalculæ? They move and devour their prey. Placed, so to say, on the threshold of life, at the common origin of the innumerable generations which are born and die on the earth, they naturally appear to us as the ancestors of all the species more and more differentiated, which succeed each other in parallel series up to the tree and the mammal. For it is in them that, perhaps unconsciously, that special activity arises which in the higher organisms manifests itself with such great energy. Besides, we do not know what life is in those primeval shades where the germs are elaborated, where matter is disengaged from the rock or from the ooze, to change into little separate worlds. It is only by the consciousness of his own life that man can judge of that of other species: he takes his place proudly apart, and yet it is by bringing all into relation with himself that he establishes the series of living creatures.

The number of animals is probably not less than that of plants. The number of species is estimated provisionally at 260,000 or 280,000; but in reality it is unknown, excepting for the higher groups; and it is precisely these groups which are less rich in animals of different forms The first class, that of the mammalia, is also distinguished from all the others by the least considerable number of representatives. Scarcely 1400 can be counted on the entire surface of the planet, in the waters and on the dry land. According to M. Sélys-Longchamp, there are in Europe only 121 species of terrestrial quadrupeds, and in this relatively small total it is the small-sized animals that form by far the greater number. In the same way, of the 8000 varieties of birds known to naturalists, more than 5000 are of a size not exceeding the sparrow. The insects, much smaller on an average than the animals of all the higher classes, comprise in themselves alone more than 150,000 species, that is to say, about three-quarters of the whole fauna already studied by scientific men. And yet below the world of insects, crustaceans, molluscs, worms, and echinoderms, moves an immense swarm of animalculæ, which are at once the admiration and the despair of those who seek to investigate them by aid of the microscope. The organs of these wonderful creatures escape our

sight, often even the drop of water in which they move and which is their universe is invisible to the naked eye; but they compensate for their smallness by the variety of their forms. Man can certainly attempt, thanks to method and accumulated observations, to enumerate the infinitely small species; but the task is hardly begun, and it is pursued with difficulty beyond the world of visible insects in that obscurity where only the thought of the mathematician seeking to apprehend atoms has penetrated. At all events, that which we already know enables us to recognize, at least from the mammal to the insect, a law of progression according to which the species are more and more rare in proportion as they rise in the series of beings. In acquiring complication of structure they lose in diversity of form; they improve, and become, so to say, a *résumé* of the inferior species, but at the same time they are more and more limited in number, as if nature required more strength to produce them. By a remarkable contrast, it is precisely the contrary that we observe in the vegetable world. There it seems that the numbers of species and individuals increase in proportion to their degree of development. The phanerogams have many more representatives than the cryptogams. The dicotyledons are more numerous than the monocotyledons, and in these two great divisions of plants with visible flowers it is the highest families, the graminaceous and composite plants, which are also the richest.

If the multitude of species which constitute the whole of the earth's fauna does not yield in number to that of the flora, the host of individuals is equally innumerable; nothing more numerous can be imagined than the herbs and vegetables of every sort which clothe the surface of the earth. It is true that in consequence of their relative independence, animals are much less visible in nature, while vegetation forms a continuous carpet over the globe, and the green of the trees or the grass appears to us like the normal colour of the surface of the earth; animals, hidden under the verdure or in holes in the ground, seem at times to be completely absent from the landscape. On the other hand, the vegetables, requiring a nourishing soil to support them, spread over its surface alone, while a number of animals can, owing to the freedom of their movements, be accumulated in enormous masses on the earth, or fly in clouds towards the sky, or else move in myriads in the depths of the sea. The atmosphere and the ocean, no less than the surface of the earth, are the domain of animal life; it is only by millions that one can estimate the number of the passenger-pigeons of the United States, where flocks, traversing the sky with a speed of 50 miles an hour, take three days in passing by; it is by milliards that we estimate the locusts which descend upon the provinces and cover them with blackish masses, glittering in the sun like a sort of cuirass, whilst they eat up all plants to the root. Finally, all calculation becomes impossible and imagination itself is powerless, when we would speak of the clouds of gnats which darken the air above the marshes of Louisiana and Columbia, or over the grand lakes of North America; and particularly when we think of the innumerable organisms which swarm in the ocean. There is, therefore, an equilibrium, so to speak, between the two forces striving for the possession of the earth, between the flora and the fauna, the vegetable world and that which feeds on it.

The poets of former times, according to Homer, were pleased to give to the sea the epithet of "barren," and yet nothing equals its exuberant fecundity. Much more than the earth, of which the surface only is richly peopled, the ocean is the domain of life. Not only its upper sheets, but also the deeper strata, are filled with organisms of every kind; in certain parts the myriads and myriads of

creatures are crowded in such prodigious multitudes, that the waters themselves, so to say, are alive. There may perhaps be found in the vast watery tracts some deserts almost entirely destitute of life; but these are exceptions, and in most of the regions of the sea every drop of water is a world from the multitude of beings that inhabit it. Taken as a whole, the ocean may even be considered the special centre of life. It is in the waters, swarming with animalculæ, that continents are gradually formed, by the deposit of organic remains. New generations unceasingly at work lay the foundations of future continents. It is in the sea, too, as palæontologists tell us, that the primitive species must have originated, from which all the present forms, oceanic and terrestrial, are descended. The great basin of the seas is the cradle of life. "Water is the beginning of everything," said Thales of Miletus 2500 years ago.

A long time ago Humboldt made the remark that the ocean is, in contrast to the emerged lands, the principal centre of animal organisms, while the continents are in especial the domain of vegetable life. In fact, the waters of the sea often owe their colour and phosphorescent brightness to the numberless animalculæ which are developed there in prodigious quantities. Over immense extents the bottom of the ocean, as discovered by the sounding-lead, is an animated ooze, each cubic inch of which contains millions of living creatures. The earth, on the other hand, excepting where in desert regions it is unprovided with water, is naturally covered with a carpet of verdure, plants, large trees, and innumerable parasites. The forests of polypes, in the South Seas, the polythalamia, which fall like snow from the surface of the water to the bottom of the Atlantic, the banks of herrings and *strömlings*, where the fish are as thick as the grass of the prairies, find their contrast in the seas of foliage on the plains of the Amazon, in the undulating savannahs which stretch beyond the sight, and even in the cultivated fields variegated with so many different plants.

CHAPTER LVIII.

THE OCEANIC FAUNA.

THE contrast between the land and the seas manifests itself also in the respective dimensions of their forms of life. The ocean, so rich in infinitely small organisms, numbers also among its animals monsters far larger than those of the dry lands, while the greater part of its plants, and even those prodigious fuci several hundred yards in length, are nothing but simple strips, and present neither roots, trunks, nor branches which may be compared with the oak, the baobab, and the chestnut. As to the organization, it is of the most rudimentary kind. With the exception of a single family of phanerogams, the marine algæ are all of the lower orders of plants without apparent fructification. The pelasgian plants have neither calyx, nor corolla, nor stamens, nor pistils. On the other hand, many animals are fashioned like flowers, and the earliest naturalists were often deceived by them. For a long time the most learned among them, and even Reaumur himself, saw in these polypes real plants; and in our day many investigators have demanded if the algæ were not also, like the branches of coral, a kind of structure of vegetable form built by innumerable social animalculæ. In any case, it is certain that the generating granules of algæ move exactly like animalculæ, and, as it seems, "by an act of their own will;" they come and go, advance towards the light, and only fix themselves after having found the place that suits them in which to build their cellules. This is one more proof that the division between the two series, vegetable and animal, is in great part artificial.

In their love of the marvellous, and perhaps also because of the terror which the sight of these monsters of the sea had occasioned them, our ancestors gave to these gigantic animals a size out of all proportion with their real dimensions. Numerous are the legends which speak of whales on which one could disembark as on an island, but which then plunged suddenly and left their visitors fighting with the waves. The seamen of all nations recount also a host of stories about monstrous serpents, which unrolled their rings over several large successive waves, and of polypes whose arms, incessantly in motion, resembled a forest agitated by tempests. The observations made by naturalists do not confirm these tales; but it is certain that whales have been measured more than 100 feet long and 65 feet in circumference, weighing nearly 200 tons, that is to say, more than an army of 3,000 men. Scoresby saw a rorqual more enormous still, which was no less than 120 feet from head to tail. As to monsters of the size of the hippopotamus or the elephant, such as dolphins, orcas, cachalots, walruses, and sharks, the species are very numerous, and we often meet with individuals of this dimension in groups of

hundreds and thousands in a limited space. Among the marine animals of an inferior order, such as the cephalopods, there are some also of a prodigious size; thus specimens of the *Cyanea arctica* have been fished out of the bay of Massachusetts, 6½ feet in thickness and the arms of which were not less than 114 feet long. And certainly it may be asserted beforehand that the ocean still keeps in reserve many surprises for naturalists who will explore all its abysses.

Recently Panama Bay alone has yielded over a hundred new shells of molluscs. Numerous species which were supposed to be extinct, and which were said to be found only in the geological fossiliferous strata, have also lately been discovered in the marine depths. Amongst them are no less than twenty-eight species found in the Mediterranean waters.

Still, if the sea may be considered as the principal theatre of animal life, it is not so much because of the size and strength of its monsters as by the prodigious multitude of creatures which are agglomerated in rows, heaped up in banks, and swarm in immense beds. It is easy to imagine what innumerable armies of fish must fill the ocean, since a single female may lay a hundred thousand, a million, or even more than ten millions of eggs. In the second generation a single couple of these fish may have given birth to a hundred trillions of individuals; in the third generation the entire sea with its unfathomable abysses would be filled with a compact mass of fish. But even before they are born their numberless progeny is pursued by equally numerous enemies. The sea is an immense field of carnage, where the creatures which are born in infinite myriads serve also as food to millions and tens of millions of furious devourers. When the herrings penetrate into the North Sea "it seems as if an immense island had risen, and that a continent was about to emerge;" but this island or continent of fishes is beset and eaten on all sides. Each detachment of the mighty army, about thirty miles long and from five to six broad, is accompanied by legions of cetacea and other great sea animals, which press in bands around the serried columns, and never cease swallowing herrings by hundreds; birds flying in clouds above the scene of the immense slaughter plunge down on all sides to select their victims; an oily substance, resulting from the thousands of torn fish, floats on the surface of the sea. When at last the fishermen, warned of the approach of the bank of herrings, rush to their capture, the massacre assumes the most frightful proportions. The fishermen of the single district of the Göteburg kill as many as a hundred and fifty millions of herrings in a single campaign; those of Bergen three hundred millions; those of Yarmouth even more. The number of herrings captured during the fishery by the seamen of northern Europe must be estimated at many hundreds of millions.

There are certain parts of the ocean where the fish are still more numerous than on the coasts of western Europe; such is for example the Bank of Newfoundland, where, in consequence of the meeting of two marine currents differing in temperature and the fragments they bring, all the conditions favourable to the development of a great diversity of species are found united. It is in the neighbouring seas that the Esquimaux, whose name signifies "eater of raw fish," finds his food in abundance: it is there that the fishermen, English, French, and American, go each year to seek their provisions from the two or three millions of codfish left by the multitudes of cetaceæ that are always at work. In the North Pacific, on the shores of Japan, round the Canaries are other fisheries scarcely less rich, whence the net is sure to bring each time numerous victims.

As to the marine animals other than fish, a number of species swarm in masses

all the more compact the smaller the individuals themselves are. From the heights of the promontories, which rise in peaks above the gulfs of New Granada, to the east of Santa Marta, the sea is sometimes seen as far as the horizon filled with yellow medusæ, so crowded one against the other that the colour of the water is quite changed by them. A swarm of medusæ, through the midst of which Piazzi Smyth passed in July, 1856, to the north of the Canaries, occupied a space about 45 miles wide, and comprehended in the superficial bed alone two hundred and twenty-five millions of individuals. Whales and other cetaceæ devoured enormous quantities of these graceful orange-veined medusæ, and, on their side, each of these animals absorbed myriads of siliceous diatoms. The quantity of these inferior organisms contained in the stomach of each medusa amounts certainly to seven hundred thousand; it is therefore by tens of thousands and by millions that we must estimate the creatures swarming in each wave. Sailors, accustomed to see the innumerable multitudes of medusæ, only see in them "the scum of the sea;" and Bacon himself, that great observer, thought that the marine jelly-fish were nothing else than "heated foam." More poetically, the Peruvians of the coast of Iquique give to one of these animals the elegant name of *Aqua viva*, or "living water."

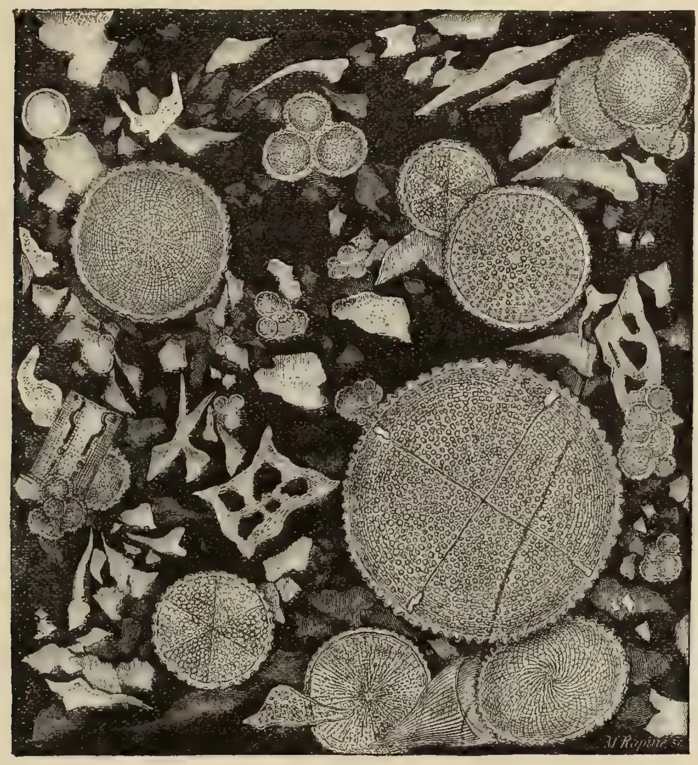
Sometimes the sea is so filled with living organisms that one might call it saturated, and its colour is entirely changed by the floating multitudes. Thus on the coasts of Greenland seamen traverse broad bands of a deep brown or olive-green colour, being frequently 180 and even 250 miles long; they are banks of medusæ, every cubic inch of water containing hundreds, and swallowed by hundreds of thousands in every mouthful of a whale. Elsewhere navigators observe immense "sea-serpents" formed by innumerable salpas, which are attached to one another like the particles of one and the same body; or else they form expanses without visible limits, some red as blood, others white as milk. There they are not banks, but *worlds* of animals, where each drop contains as many as there are stars in the Milky Way. In August, 1854, Captain Kingman traversed in the Indian Ocean a space more than 25 miles wide, the whiteness of which was dazzling enough to extinguish the light of the stars; and when the sea of animalculæ was passed, the sky above it was for a long time seen to shine as with the light of a feeble aurora borealis. Ten years later the vessel *La Sarthe* found again in the same part a vast "sea of milk," where the furrow of its prow made a black line.

Is not, however, the marvellous phosphorescence of the waters, due in great part to living animalculæ, the most astonishing testimony to the innumerable host of organisms which swarm in the ocean? There is no voyager who has not observed during the night those sheets of yellow or greenish light which tremble on the sea, those sheets of lightning which spring from the crests of the waves, those whirlpools of sparks which the prow of the vessel causes in its plunge, those waves of flame which glide from either side of the ship to unite in long eddies behind the rudder, and transform the track into a river of fire. In the port of Havannah the least object which agitates the surface of the water appears suddenly like a line of flame, and raises around it a whole series of luminous wavelets, propagating themselves in concentric circles to several yards in distance. Boats sailing over these waters, driven by the equal movement of the oars, leave behind them the trace of an immense fiery dragon with large paws extended. In the Persian Gulf, Palgrave tells us that the waves are so luminous during the night that the Arabs attribute these reflections to the infernal fires shining through the

rocks beneath the transparent mass of waters. Modern science explains to us the phenomena of the phosphorescence otherwise. According to the researches of Boyle, Forster, Tilesius, and Ehrenberg, this light results from innumerable animalculæ, some living and others in decomposition.

The little organisms called foraminifera, because of the numerous holes in their shells, are probably the creatures which people the tracts of the ocean in the greatest multitudes; the bottom of all the seas is, without exception, strewn with their thin calcareous shells, of which one drachm of sand contains sometimes nearly 16,000, according to a calculation of M. d'Orbigny. Among the various genera of this family, which comprehends nearly 2000 known species, the globigerina, which has an ovoid or spherical shell, may be considered as the special oceanic genus,

Fig. 173.—Organisms from the Sea-bottom.



since it is met with in all latitudes and at depths varying from 50 to 3000 fathoms. Their remains cover thousands of square miles of surface at the bottom of the ocean; and when the lead brings up specimens of the ooze, it is often found that it is composed of 75, 80, or even 97 per cent. of the skeletons of a single species of globigerina. The rest of the sediment is formed of other débris of little animals, spicules of sponge, and star-fish. Besides these, there are the siliceous organisms the diatoms, which aid in filling up the marine depths. But do these bodies of such a perfect regularity, disks and triangles, parallelograms, pyramids, and other geometrical figures, all so gracefully ornamented with the finest arabesques, belong to the vegetable world? The botanist Schleiden believes so. Or are they rather animals? The zoologist Ehrenberg asserts it. But whether they be plants or

animals, they are not the less one of the most important agents in the continuous formation of our globe.

The prodigious variety of the marine fauna has been well illustrated by the results of the Norwegian North Atlantic expedition of 1876-78, which in a comparatively limited area fished up from depths of 500 to 2000 fathoms as many as eighty-two species of crustacea, representing no less than sixty-one distinct genera. To account for this surprising diversity of types, it has been suggested that the conditions of oceanic life are so hard, and the struggle for existence so severe, that each individual peculiarity becomes intensified, and that not only the cold, but the darkness, may produce considerable changes in their organisation. Absence of colour and absence of sight are the prevailing characteristics manifested by every species. The loss of the eyes seems to stimulate the development of all the tactile organs to supply their place, so that the same peculiarities of structure are found exhibited in these oceanic depths as have been noticed in the crustacea of the American and Austrian caves, and from the dark underground waters of various parts of the world.

As regards the bathymetric distribution of the Annelids and other smaller oceanic organisms, the naturalists of the *Challenger* expedition found that the greatest number of species occurred in the shallow water, 10 fathoms and under. The two regions ranging from 10 to 50 and from 50 to 100 fathoms have each about the same number of Annelids, and both are similar in respect to new forms. In the depth between 100 and 200 fathoms the number was less, but the proportion of new forms was much higher; while in depths between 200 and 500 fathoms almost all the forms were new, and many belonged to new and remarkable genera; between 500 and 600 fathoms the number fell to less than half that in the previous group, but the majority were new. The number found between 600 and 1000 fathoms include two known species out of a list of 14. The four species occurring between 1000 and 1200 fathoms are new. Those species found between 1200 and 1500 fathoms are more than five times as numerous as the last, and include only five known forms, most of which, however, are found in shallow water as well as at this great depth; between 1500 and 2000 fathoms all the species were new. The same is true of those between 2000 and 2500 fathoms; while in the lowest depths, between 2500 and 3000 fathoms, several known forms occurred. The majority of the deep-sea forms are tube-dwellers.

On the general subject of oceanic life Mr. John Murray observes:—

"The advances during recent years in the knowledge of the forms of life inhabiting the floor of the ocean surpass those in any other department of oceanic investigation. Thousands of new organisms have been discovered in all seas and at all depths in the ocean, and either have been, or are now being, described by specialists in all quarters of the world. There does not seem to be any part of the ocean bed so deep, so dark, so still, or where the pressure is so great as to have effectually raised a barrier to the invasion of life in some of its many forms. Even in the greater depths all the great divisions of the animal kingdom are represented.

"As might have been expected, forms of life are most rich and varied in the shallow water surrounding the continents, where there is abundance of food, sunlight, and warmth; where there is motion, rapid change of water through currents, and other congenial conditions. At the depth of half a mile there are still numerous animals, though many of them differ from those of shallower depths, but plant-life seems to have wholly disappeared, if we except the diatoms and

calcareous algæ, whose frustules and skeletons have fallen to the bottom from the surface, carrying with them some of their protoplasm and chlorophyll.

"At the depth of one mile there are a few animals which are barely distinguishable from, if they be not identical with, shallow-water forms; but the majority of the animals are specifically distinct from those found within the 100-fathom line, and many of them belong to species peculiar to the deep sea, and are universally distributed over the ocean bed in deep water.

"As we descend into still deeper water, and proceed farther seawards from the borders of the continents, species and the number of individuals become fewer and fewer, though they often present archaic or embryonic characters, till a minimum is reached in the greatest depths farthest from continental land. Distance from continental land is, indeed, a much more important factor in the distribution of deep-sea animals than actual depth.

"If we neglect the Protozoa and compare the results of twelve of the *Challenger's* trawlings and dredgings in the central line of the Pacific, in depths greater than 2000 fathoms, on globigerina ooze, radiolarian ooze, and red clay, with twelve trawlings and dredgings taken under similar conditions and depths, but on the blue and green muds within 200 miles of the continents, we find that the Central Pacific stations have yielded 92 specimens of animals belonging to 52 species, all, with two doubtful exceptions, new to science, and among them 13 new genera; on the other hand, the stations near the continents have given over 1000 specimens belonging to 211 species, of which 145 are new species and 66 belong to species previously known from shallower water. These numbers are not final, but the proportions are not likely to be greatly altered when the whole of the *Challenger* reports are completed. These facts may be in part explained by the greater abundance of food present in the continental débris which forms the chief constituent of the terrigenous deposits; but it is probably more closely connected with the greater distance of the seaward stations from the original place of migration. We must suppose that all deep-sea animals have been derived originally from shallow water; those which descended first into deeper water have, generally speaking, been able to migrate to a greater distance seawards than those which set out later, and being derived from older stocks they have retained in the great deeps some of the characters which are now regarded as archaic and embryonic.

"Although no new types of structure have been discovered in organisms from the deep sea, the peculiar modifications which animals have undergone to accommodate themselves to abysmal conditions are sufficiently interesting and remarkable; the eyes of some fish and crustaceans have become atrophied or have disappeared altogether, while in others they have become of exceedingly large size or have been so modified as to be scarcely recognisable as eyes: for instance, in the case of the scopelid fish *Ipnops;* fins and antennæ have become extraordinarily elongated, and at times appear to simulate the alcyonarians of the deep sea. The higher crustacea and some families of fish have very few and very large eggs in the deep-sea species, while their shallow-water representatives have a very large number of very small eggs, showing apparently that the deep-sea species have relatively few enemies. While some groups, for instance the Pycnogonids, Tubularians, and Nudibranchs, have much more gigantic representatives in the deep sea than in shallow water, the representatives of the majority of groups, and especially the Gasteropods and Lamellibranchs, are much smaller, and generally speaking have a dwarfed and delicate appearance, the shells being poorly supplied with carbonate of lime. Indeed the solid tissues of most deep-sea animals are but feebly

developed when compared with shallow-water forms. The experienced dredger has, as a rule, little difficulty in recognising a deep-sea species in a dredging from its general appearance. Many deep-sea animals emit, and some have special organs for the emission of, phosphorescent light, which appears to play a large *rôle* in the economy of deep-sea life.

"One of the most striking facts with respect to deep-sea animals is their very wide distribution—the same species being found in all the great ocean basins. At the depth of half a mile identical species are dredged off the coast of Scotland and off the coast of Australia at the Antipodes; the nearly uniform conditions existing everywhere at depths greater than half a mile, facilitates the wide distribution of species which have once accommodated themselves to a life at that depth. The same consideration probably explains the occurrence of some identical and nearly identical species in the shallow waters of the temperate and polar regions of both hemispheres.

"Among the higher crustacea the Brachyurans, which are regarded as a modern group, are found in great numbers in shallow waters, but have very few representatives in deep waters, and appear to be quite absent from the abysmal regions. On the other hand, the representatives of the Schizopoda, Anomoura, and Macrura, which are regarded as older groups, are widely distributed in the deep sea; many similar instances of this kind could be given. The stalked Crinoids, the Elpididæ among the Holothurians, the Pourtalesiæ and Phormosomas among the Echinids, and other groups, have now no representatives in depths less than 100 fathoms, but are widely distributed in all greater depths; while many genera are confined to the abysmal regions. We are not as yet, however, in a position to fully discuss many curious points in distribution.

"It may be urged that after all the few hundred scrapings of our small trawls and dredges can give but a very inadequate idea of the condition of things over the millions of square miles covered by the ocean; but against this it may be argued with great force that as the same animals and deposits occurred again and again with little variation, we doubtless have even now a tolerably complete knowledge of deep-sea life.

"When we turn to the surface waters, one may exclaim: it is a dull and stupid soul that would not rejoice at the first acquaintance with the teeming pelagic life of the ocean, rich in bizarre forms and varied colours, or that would not be struck with wonder at the magnificent displays of phosphorescent light sent forth on a dark night from the surface of an equatorial ocean, like flashes of 'spirits from the vasty deep.'

"Beyond the shadow of the ship
I watched the water-snakes;
They moved in tracks of shining white,
And when they reared the elfish light
Fell off in hoary flakes.

"Within the shadow of the ship
I watched their rich attire;
Blue, glossy green, and velvet black,
They coiled and swam, and every track
Was a flash of golden fire.

"Oh, happy living things! No tongue
Their beauty might declare.
A spring of love gushed from my heart,
And I blessed them unaware.

"Experiments with tow-nets have shown that life exists in all the intermediate waters of the ocean, between the surface and the bottom, yet sparingly there when

compared with what occurs just above the bottom, or more markedly when compared with the abundant and luxurious development of life in the surface and sub-surface waters.

"In mid-ocean the majority of the organisms are quite distinct from those usually found along the coasts in bays and estuaries, though, like the deep-sea animals, they were, in all probability, originally derived from the shallow waters around the continents. There are species of diatoms, calcareous and other algæ, many foraminifera, siphonophora, a few annelids, many crustaceans, numerous pteropods, heteropods, and other molluscs, the pelagic tunicates, and many fishes whose home is in the great systems of oceanic currents. It is only occasionally, or in special localities, that some of the species are borne to continental shores, for the members of this oceanic pelagic fauna and flora appear to be killed off where the ocean is affected by the fresh waters from the land. In the equatorial regions the species and individuals are most abundant, and they vary with temperature, latitude, and the salinity of the water.

"In the Antarctic or Southern Ocean diatoms abound at the surface, and in the same region the sea-floor is covered with their dead siliceous frustules, which form a *diatom ooze.* In the middle and western Pacific, where the surface water is less salt than in the Atlantic, the radiolarians, which likewise secrete silica from sea water, occur in vast numbers at the surface and in intermediate waters, and in these regions their dead shells and skeletons make up the chief part of the deep-sea deposits known as *radiolarian ooze.*

"But it is those species belonging to the varied pelagic oceanic organisms which secrete lime for their shells and skeletons that are principally forced on our attention, both from their prodigious numbers and the part played by their remains in the formation of deposits. These species flourish especially in the warmest and saltest waters. In a square mile of equatorial water 600 feet deep it is estimated that there are over sixteen tons of carbonate of lime in the form of shells, which belong to about thirty species of calcareous algæ, foraminifera, pteropods, and heteropods. When these surface organisms die and fall to the bottom they form the deposits known as *pteropod* and *globigerina oozes.* In descending they, as well as other surface organisms, carry down with them some of the organic matter of their tissues, which, not decomposing rapidly in the cold deep water, forms the chief source of nourishment for deep-sea animals, and the chlorophyll which Professor Hartley has discovered in some deep-sea deposits is probably derived from diatoms which have fallen to the bottom in this way.

"It is, however, a very remarkable fact that the dead shells of these foraminifera and pteropods are not found on the bottom of the sea beneath all the regions where they flourish abundantly at the surface. They are found at greater depths beneath warm equatorial waters than elsewhere, but there is barely a trace of them in all the greatest depths, although in an adjacent area, where the surface and intermediate conditions are the same, but where the depth is less than three miles, they may make up seventy-five or even ninety per cent. of the deposit. It has been abundantly proved that when sea-water, and especially sea-water containing absorbed carbonic acid, passes over a dead shell or coral, the lime is gradually removed, being carried away by the water as bicarbonate in solution; and the shell or coral is removed more rapidly the more surface it presents to the water in proportion to the amount of carbonate of lime present in the shell. This is what happens to pelagic shells as they fall through the water to the bottom. Where the depth is not very great only the thinnest and most delicate shells are removed,

and the others accumulate, forming vast deposits; with increasing depth other shells disappear, only the thicker ones reaching the bottom; but in the very greatest depth nearly every trace of these surface shells is removed, or we find them making up but 1 or 2 per cent. of the deposit. It is possible that this process of solution of the shells may be somewhat accelerated in the deepest layers of water by the great pressure.

"In the deepest parts of the abysmal areas, where the carbonate of lime shells are either wholly or partially removed from the bottom, there are met with those peculiar deep-sea clays, the origin of which has been the subject of considerable discussion. They are principally made up of clayey matter resulting from the disintegration of volcanic rocks, and derived chiefly from floating pumice and showers of volcanic ashes. Mixed up with these clayey and volcanic materials are thousands of sharks' teeth, some of them of gigantic size, and evidently belonging to extinct species; also very many ear-bones and a few of the other bones of whales, some of them also probably belonging to extinct species. These organic fragments are generally much decomposed and surrounded and infiltrated by depositions of peroxide of manganese, which is a secondary product arising from the decomposition of the volcanic material in the deposits. Again, we have in some places numerous zeolitic minerals and crystals formed in the clay, also as secondary products. Lastly, there are numerous minute spherules of native iron and other rare substances, covered with a black coating of oxide, which are referred with great certainty to a cosmic origin—probably the dust derived from meteoric stones as they pass through the higher regions of our atmosphere. Quartz, which is so abundant as a plastic element in deposits around the continents, is almost absent from the deposits of the abysmal regions.

"In the abysmal regions, then, which cover one half of the earth's surface, which are undulating plains from two to five miles beneath the surface of the sea, we have a very uniform set of conditions: the temperature is near the freezing point of fresh water, and the range of temperature does not exceed 7°, and is constant all the year round in any one locality; sunlight and plant-life are absent, and although animals belonging to all the great types are present, there is no great variety of form nor abundance of individuals; change of any kind is exceedingly slow. In the more elevated portions of the regions the deposits consist principally of the dead shells and skeletons of surface animals; in the more depressed ones they consist of a red clay mixed with volcanic fragmental matter, the remains of pelagic vertebrates, cosmic dust, and manganese iron nodules and zeolitic crystals, the latter being secondary products arising from the decomposition of the minerals which have long remained exposed to the hydrochemical action of sea-water. The rate of accumulation is so slow in some of these clays that we find the remains of tertiary species lying on the bottom alongside the remains of those inhabiting the present seas. It has not yet been possible to recognise the analogues of any of the deposits now forming in the abysmal regions in the rocks making up the continents."

CHAPTER LIX.

INFLUENCE OF CLIMATE AND PHYSICAL CONDITIONS ON THE SPECIES OF ANIMALS.

ANIMALS, like plants, depend on all the conditions of climate; heat and cold, light and darkness, dryness and moisture, influence them in various ways, and give them a clearly-defined area of habitation. Nevertheless, a great number of species possess an advantage over the plants, for while these latter cannot fly spontaneously before an ungenial climate, and the displacement of their race takes centuries in accomplishing, animals, endowed with locomotion, can more readily migrate to countries which offer a temperature suited to them. Hundreds of species of birds and fishes, numerous tribes of insects, migrate every year, and are thus able, owing to the two countries which they inhabit by turns, to enjoy all the conditions of heat, light, and moisture favourable to their well-being. There are birds of passage, which travel several thousands of miles in a few days, and go from one continent to another over wide seas. Thus at the commencement of September the stork, dreading the severe cold of North Germany, abandons the thatched roof to perch on a cupola of Egypt or Tunis; then in the month of March, when the African climate becomes too dry and burning, it resumes its flight, and crossing the Mediterranean, passes the high Alps, either on the east by the Engadine or on the west by the Jura, and alights once more on its nest, respected by the peasant.

In the climate of temperate Europe nearly a hundred birds, among them the crane, the lark, the passenger-pigeon, the quail, and the swallow, travel thus alternately from north to south and from south to north, to avoid the extreme temperatures, and perhaps still more to find an abundance of food at all seasons of the year; it is even possible that certain species cross the equator during the migrations, and by this coming and going they constantly enjoy a summer temperature, now in one hemisphere, now in another. Several species of mammalia make similar journeys: the vast prairies of North America witness each year the immense migrations of the bisons, field-mice, and musk-rats defiling in innumerable multitudes. In mountainous countries, too, animals can easily change the climate without traversing vast spaces; it is enough for them to climb the mountain, and then to descend again to the plain. Some of the monkeys of Hindostan take refuge during the summer in the high valleys of the Himalayas, as far as 10,000 feet high, and return to the low forests of Terai at the approach of winter; in the same way the reindeer of Lapland follow the snow, which now accumulates, and now melts on the mountain slopes.

To avoid the extremes of temperature, either the cold of winter or the too great heat of summer, certain species of animals have also the resource of burying themselves in the ground. The greater part of the insects pass their existence as larvæ under the bark of trees, under heaps of leaves, or beneath the superficial strata of the earth. Some species of molluscs and fish, several reptiles, and a few mammals, hide themselves also in the mud of the lakes and marshes, or in burrows hollowed out beforehand. Thus protected from the climate out-doors, the animals fall into a state of torpor, during which their life remains partially suspended; the temperature of their bodies sometimes sinks to freezing-point, and fish have even been seen completely frozen, without this apparent death having prevented their resuscitation later; respiration and circulation of the blood are gradually slackened, and digestion ceases entirely; the organs becoming temporarily useless are restricted; even the intestinal parasites are numbed with the animals upon which they live. This long period of sleep is, however, a phenomenon which is found much more generally in the vegetable world. For, in fact, all the plants of the frigid and polar zones repose in the winter, and only live by their stems and roots; even in warm countries, the plants present a remarkable periodicity in their existence.

Although the privilege of locomotion permits a number of animals to enlarge their domain considerably, the species do not the less remain subject to climatic conditions, and all have an area of habitation limited either towards the pole by the severity of the cold, or towards the equator by too great heat. Each climate has its particular fauna, which, in order to live and propagate itself easily, requires certain normal conditions of temperature and moisture. There are animals which cannot quit the torrid zone without perishing, or living an artificial life, like most of those transported at a great expense to our zoological gardens; other species die if they are taken from the northern countries, covered with ice during the greater part of the year. The field-mouse seen by M. Martins on the Faulhorn, and certain animalculæ such as the *Desoria nivalis* and the *Podura hiemalis*, have their dwelling in the snow, or on the ground covered by it. On the other hand, certain rotifers exclusively inhabit thermal waters; a Scarabæus, the *Hydrobius orbicularis*, lives in the sources of Hammam-Meskoutine, the temperature of which is 131°. In the seas the whale and various cetaceæ are arrested by the warm waters of tropical latitudes as if by a barrier of flame, while the cachalot and the sea-cow swim only in the tepid waters of the equatorial ocean. In the same way the coral-insects are only seen in seas whose temperature is above 72° F.; at 60° they can still live, but without developing their branches. The Gulf-stream, which carries into the northern seas the warm water from the Antilles and Bahamas, carries also with it multitudes of southern species, which never stray either to the right or left into the colder waters of the Polar current. The two masses of water flowing parallel to each other, but in an opposite direction, have each their distinct fauna, whose barrier of separation is an imaginary line between two zones of different temperature, varying according to the seasons and the advance of the waters. As to the superior animals which man brings with him into almost all the countries of the world, they are modified considerably under the influence of the climate. Horses and dogs brought from England to the Himalayan mountains are clothed with a thick wool that grows amongst their hair; in equatorial Africa, on the contrary, the dogs and sheep become bald, and fowls lose all their feathers, with the exception of the larger feathers of the wing.

The influence of light is shown also in a very remarkable manner by the

atrophy or even the complete suppression of the organs of vision in the fishes and other animals which inhabit the depths of caverns. The colour of the skin, too, changes in most animals according to the brilliancy of the rays that shine on them. The fauna of caverns assumes a dusky and uniform livery, which is lost in the surrounding darkness, while outside in the splendour of the sunlight the brightest butterflies and birds fly like winged flowers, no less brilliant than those of the meadow. The animals of the tropics, especially the insects, fish, and reptiles, shine in much brighter colours than those of similar species from the temperate and glacial zones; thus, as M. Radau says, "the sun depicts itself in the fauna of a country." Finally, in the same individual the action of light manifests itself by the contrast of colours, glittering on the back or upper surface of the wings, duskier on the belly or the underpart of the plumage which remains in the shadow. The habits of most species are also regulated by the alternations of light; mammals, birds, reptiles, fish, insects, and molluscs, have all their period of daily activity clearly defined, either by the setting or the rising of the sun. Among the insects especially, the awakening of each species by day, by night, or by twilight, is accomplished with a singular regularity. The mosquitoes of certain tropical regions succeed each other in the air at a fixed hour, well known by the natives, who, by imprisoning the insects which persecute them are able to measure time no less easily than by that ingenious "floral clock," where each hour is marked by the expansion of a corolla.

All the animals which inhabit the sea or the continents equally require air in order to live; but this air must be more or less pure, more or less charged with moisture, according to the species. Many birds, accustomed to rove through space, perish rapidly in the midst of a corrupted atmosphere, and even their eggs cannot be hatched there; the intestinal worms, on the contrary, and the innumerable species of animals which feed on decaying matter, and thus perform the office of scavengers in nature, can accommodate themselves very well to an air mixed with impure gases. Fish, too, and other aquatic animals, with the exception of the cetaceæ and swimming birds, directly respire oxygen dissolved in water. As to moisture, it is equally indispensable to life; but while certain species live on the borders of marshes or rivers, in an atmosphere loaded with vapour, there are others, especially the numerous tribe of lizards, which delight in the rock or dry soil of desert lands destitute of water.

To a recent number of *Nature*, Mr. A. R. Hunt communicates a valuable paper "On the Influence of Wave-currents on the Fauna of Shallow Seas," in which he remarks:—

"My own experience in the matter is as follows:—Holding the orthodox view of the peaceful repose existing on the sea-bottom, I commenced cruising, some twenty years ago, on that excellent natural experimental tank, Torbay. I soon found, to my surprise, that the local fishermen and dredgers were as confident that the waves greatly disturbed the bottom as naturalists were of the reverse. Having kept my eyes open in this direction, I submitted a paper to the Devonshire Association in 1878, descriptive of the levelling action of the waves on the six-fathom area of Torbay (*Trans. Dev. Assoc.*, vol. x. p. 182).

"With the kind assistance of Lord Rayleigh I was enabled to show that theory and observation were in complete accord as to the energy evinced by the waves in the particular instance under consideration.

"Having learned from Lord Rayleigh that wave-action at the sea-bottom takes the form of reciprocal currents, I was led to make some experiments and observa-

tions on the formation of ripple-mark. In the course of this investigation I was soon impressed with the conviction that these alternate currents held at their mercy the marine fauna exposed to their attacks, and that the zoological side of the problem was at least as important as the geological. Accordingly, an outline of the subject in its zoological aspect was included in a paper on ripple-mark read to the Royal Society in 1882 (*Proc. R. S.*, vol. xxxiv. p. 1).

"Having come into possession of confirmatory evidence of the action of waves at a depth of forty fathoms in the English Channel, I submitted the facts to the British Association at Southampton in the same year, 1882. This paper, sent in to Section A, was handed on to Section C, a mathematical friend suggesting to me the reason, and a very good reason too, that mathematicians required no evidence on the point contended for. However, the transfer only went to prove that the geologists were as sceptical as to the existence of wave-action at forty fathoms, as the physicists were satisfied as to that fact. This paper, amplified, appeared in the *Transactions of the Devonshire Association for* 1883 (vol. xv. p. 353).

"The zoological aspect of the question was submitted to the British Association at Southport in 1883; and again to the Linnean Society in 1884, in a paper 'On the Influence of Wave-currents on the Fauna inhabiting Shallow Seas.' In this paper, profiting by experience, I made no attempt to prove the fact of wave-action from observation, but relied entirely on a valuable letter with which I had been favoured by Professor Stokes, Sec. R. S. Neither at the British Association nor at the Linnean Society was any exception taken to my arguments in support of the importance of wave-action on the fauna affected; nor, so far as I am aware, has my position been shaken since. Now that Professor Moseley's important lecture has appeared, discussing the fauna of the sea-shore without reference to the ever-regulating wave-currents, there is considerable risk that less experienced students of natural history will in like manner pass over this promising field of research as not worthy of their attention.

"Professor Moseley states, and states truly, that the littoral fauna is adapted in various ways to withstand 'the action of the surf, the retreat of the tides, the numerous enemies;' but, beyond the reach of surf and tidal fall, agents which only affect the narrow belt of sea contiguous to the shore, the alternate currents set up by ocean waves search out the armour and test the defences of all small animals living on those extensive marine areas exposed to the ocean swell, where the depth of water does not exceed fifty fathoms.

"With respect to enemies, the waves themselves are perhaps the most formidable, as they attack and occasionally destroy whole colonies at once, whereas predatory foes rather affect the individual. For instance, let such helpless molluscs as *Aplysia* or *Pleurobranchus* wander over the sandy bottom of Torbay, as they sometimes do: the first easterly gale will sweep them out of existence. In fact, the waves so invariably prevent *Aplysia punctata* growing to its full size on the British coast, that a full-grown specimen taken in protected Guernsey waters has been considered a distinct species—viz. *A. depilans*. Similar large specimens have occurred under the shelter of the Torquay harbour works, but these, by a series of odontophores and shells, I have been able to connect with the common *A. punctata*.

"*Prima facie* it would appear that the shells of certain molluscs are more especially adapted to resist animate foes; but a close examination will often prove the contrary. Take the cases of the oyster, mussel, venus, and limpet: these molluscs are all helpless in the presence of their living enemies; the oyster

perishes by the attacks of boring-sponges; the mussel is destroyed wholesale by starfishes; the venus is perforated by carnivorous gastropods at their leisure; whilst the limpet, easily detached when taken unawares, is said to be destroyed by birds. All four are, however, admirably adapted to resist wave-currents, each in its respective habitat.

"The conclusion that the shells of molluscs are so constructed as to have comparatively but little reference to living foes is supported by the interesting fact mentioned by Professor Moseley, that hard shells tend to disappear in pelagic and deep-sea regions. That is to say, they disappear where predatory enemies abound, but where the great non-predatory enemies, the waves, are powerless or not existent. Occasionally we find the supposed protection against living enemies to be greatly in excess of requirements—*e.g.* the case of the solen, whose power of burrowing is far greater than requisite for escape from birds, but which is none too great for the evasion of waves and currents tearing away the sand in which the mollusc dwells.

"Wave-action tends to differentiate species. This can be seen in such obvious cases as *Cardium aculeatum* and *C. norvegicum*, *Venus dione* and *V. chione*. One of each of these pairs has chosen the mooring method of defence with anchor-like spines, the other that of facile penetration with smooth, unresisting shell surfaces. As these two methods are opposite in action and any compromise tends to inefficiency, the wave-currents must necessarily influence the molluscs in the direction of divergence.

"Instances of habits and forms protective against wave-currents could be multiplied almost *ad infinitum*, and, as the subject is a very interesting one, I still live in hopes that it may yet be taken up and worked out by trained observers qualified for the task."

The chemical composition of waters is most important for the organisms which live within it, and the fauna varies much in lakes, rivers, and seas, according to their proportion of salt and other substances; it is thus that the Baltic, the saltness of which at its entrance is the same as that of the ocean, and which contains in its upper gulfs almost entirely fresh water, presents at its two ends two very distinct faunas, modified by gradual transitions towards the central part. As to the mineralogical nature of the soil, it has probably a somewhat slight influence on animal life, and the modifications which the fauna of the various soils exhibit ought principally to be attributed to the difference in the plants which serve as food to the animals. Thus some land-molluscs are found exclusively on limestone formations, because the substances necessary for the formation of their shells are not found in the vegetation of other districts. The physical conditions of the soil are also of great importance to the species which hollow out burrows or subterranean passages; the mole cannot trace its wonderful labyrinths in a sandy soil, which would fall in behind it; and the ant-lion, which watches for its prey in a circular fosse, at the foot of hillocks of shifting sand, would perish of hunger if it ventured upon clayey ground. It is a strange thing that even the colour of certain species seems to correspond in a kind of secret harmony with the natural products around them. A humming-bird, that plunges with delight into an open flower, glitters like the flower itself; many fish which live in rivers with a sandy bed seem to be only thin flakes of spangled sand; moreover, a certain brown *mantis* of southern Africa lives only on a dark-coloured ground; another, entirely white, is only seen on the dazzling chalk rocks; the ptarmigan of Scotland is white as the snow in winter, and in the summer is dressed in plumage whose shades of pearly grey blend with

the delicate tints of the lichens and heather. The green leaves of our forests have for inhabitants the tree-frogs and other little creatures which match the verdure, whilst a butterfly, itself resembling a dead leaf, dances in the air among the dead leaves scattered by the wind; an orthopterous insect even seems as if it were disguised under the form of a broken beech-twig, and we might fancy that it was one of these innumerable fragments that the tempest has broken from the tree. On the Amazons River the air is filled at certain seasons with a species of white butterfly, flying in myriads like snowflakes in a storm; but amongst these butterflies are some individuals of species ordinarily distinct in colour, and which have disguised themselves in white in order to be lost in the immense crowd. How can we attempt to explain this remarkable phenomenon, which constitutes the sole means of defence of the humming-bird, of the feeble insect, of the helpless parasite, excepting by the hypothesis of "natural selection" which Charles Darwin has expounded so clearly? In the incessant struggle for existence, dating from the very origin of the species, all the individuals which cannot defend themselves by strength, cunning, scent, or venom, inevitably perish; those alone have the chance of escaping which, by their form and colour, are not distinguishable from surrounding objects. It is these who, by the gradual disappearance of the individuals visible to animals of prey, perpetuate the race; and in the succession of generations it is still the varieties most resembling the ground or plants on which they feed which save the species from destruction. Thus from generation to generation anomalies never cease to adjust themselves, and to assume in the end a permanent character.

CHAPTER LX.

FOOD OF ANIMAL SPECIES.—CONTRAST OF FAUNAS.—AREAS OF HABITATION.—CHANGES IN THE SURFACE OF THE AREAS.—BIRTH AND DISAPPEARANCE OF SPECIES.

OF all surrounding circumstances, that which most influences species, as we can easily understand, is their food. In the sea, where the flora is relatively poor and where the fauna, on the contrary, is developed with such an astonishing abundance, animals and animalculæ are almost all carnivorous; the herbivorous kind are few in number. On the dry land, on the contrary, the vegetation predominates so largely that most of the animals live upon plants, either their shoots, leaves, flowers, fruit, stem, bark, or roots. The largest animals—the elephant, rhinoceros, eland, and giraffe, as formerly the mammoth and the mastodon—feed on plants, grasses, and leaves. Most birds live on seeds, and with many of their species it is to the need of finding food, and not to the alternations of cold and heat, that we should attribute their annual or daily migrations. The life of the great majority of animals is only one long journey. Urged now by hunger, now by the necessity of seeking their safety, they come and go incessantly from one region to another, from the forests to the meadows, from the mountains to the plains, from solitudes to cultivated lands. In the valley of the lower Mississippi there is a kind of swallow, known under the name of martinet, which every morning flies in immense flocks towards the pine forests of the left bank of the river, and every evening returns and alights like a cloud on the marshy groves of cypresses on the right bank.

It is principally among insects that the intimate connection uniting the animal to the vegetable world shows itself. Many plants have their special fauna of insects, and of this eager multitude which devours them, some attack only the leaves, others the wood, or various other parts. The nettle has no less than 40 species which are born, live, and die on its stem. The birch, the willow, and the poplar are each also the exclusive home of numerous tribes of insects; the oak alone nourishes at least 184 species, more than the continent of Europe contains in mammals; every other tree than that of which they eat the wood or the bark is an unknown world to them. Thus no insect of Cayenne has become a parasite of the cabbage, carrot, vine, or coffee-plant, because these plants have been imported from distant countries, and no corresponding species is to be found in the country.

The area of habitation of each animal, large or small, which lives upon one or several vegetables, being necessarily limited by the area of the plants themselves,

it necessarily results that the carnivoræ are also quartered in the vegetable region which is inhabited by the prey on which they feed. Beyond the tropical zone, in countries where winter periodically suspends the life of the forests and meadows, the parasites of trees and grass are also for the most part condemned to sleep, either in the earth or in the plant they feed upon, and the beasts of prey which have not a period of winter sleep must suffer hunger or change their country till the return of spring. Finally, the destruction of a plant always has, as a direct consequence, the disappearance of the special fauna which was attached to it. If man fells a forest, uproots bushes, or drains a marsh, at the same time a world of animals is destroyed or exiled.

The richness of the fauna is thus in intimate connection with that of the flora: where vegetation springs from the soil with most vigour and abundance, there also animals live in the greatest multitudes. Nevertheless, we must not think that the animals of the largest size inhabit precisely those countries where the most gigantic trees grow. In this respect there is rather a contrast,—the great pachyderms of Africa feed on plateaux destitute of trees in many places, and covered with thin grass; the enormous white bear of the northern regions inhabits snow and ice-fields, far from all forest vegetation. On the other hand, the splendid forests of Brazil give shelter to relatively small species; the largest is the tapir, much inferior in dimensions to the huge animals of Africa. The most remarkable fact in the distribution of the largest species of animals is, that they inhabit the most extensive countries; it is in the Old World that the largest members of the animal world live; and the long-tailed monkeys, tapirs, vicunas, jaguars, and pumas of America are much less in size and strength than the gorillas, elephants, camels, tigers, and lions of Africa and Asia.

The number of species of animals is likewise connected with the extent of the countries. There does not exist one example of an island whose fauna is richer than the neighbouring continent; in almost all we find an enormous inferiority in this respect. Great Britain, a fragment detached from Europe, has fewer animal forms than Germany or France; Ireland has less than England; Sicily less than Italy. When the Europeans first landed on the Antilles, nearly four centuries ago, the sole indigenous mammals, with the exception of bats, which could fly over the straits, were four or five species of rodents, one of which exists still. Yet the very varied vegetation of the mountains, valleys, plains, marshes, and shores of Cuba, Hayti, and Jamaica, would have sufficed for the support of a multitude of species. In the same way, before the arrival of the English navigators, New Zealand had no other mammals than two species of bat, a rat introduced, perhaps, in a ship, a sort of otter, and a leaping animal, only the remains of which were seen. A real harmony is naturally established between each region and its particular fauna so completely that the geologist discovering very varied fossils and large skeletons in an island of small dimensions is able to affirm that it once formed part of a vast continent.

In order to resolve the important question of the distribution of animals, the naturalist must go back to the anterior ages of the earth, during which the continents were otherwise disposed than they now are. Thus the monkeys on the rock of Gibraltar bear witness to the ancient continuity of the coasts between Spain and Barbary. In other places, in consequence of the change in the forms of the continents, the former species contrast strangely with the present ones; only a strait separates two faunas, born at an interval of thousands and perhaps millions of centuries. This is the contrast observed between the archipelago of Sunda and the

group of the Australian islands. Between Bali and Lombok, which seem, however to form part of one land cut in two by the waves, and which a strait, 15 miles long, scarcely separates, the contrast of the faunas is as complete as between Europe and America. On one side quite modern species live, as if the ancient types had been gradually renewed by the neighbourhood of the vast continent of Asia: on the other, the animals have been preserved without a change in their physiognomy. In Australia we find neither cat, wolf, bear, nor hyæna; neither stag, sheep, ox, elephant, horse, squirrel, rabbit, nor any of those species of quadrupeds which we meet with in all other parts of the earth; but instead, how many animals of ancient forms, which to us seem most strange! The whole Australian fauna resembles that which formerly occupied the seas and shores of Europe during the Jurassic period; it is necessary to trace the course of the ages back to that epoch, to find animals which recall those of New Holland.

Whatever may be the enormous part to be referred to the earlier conditions of the globe to explain the present distribution of the animal species, it is certain that there is now a remarkable harmony between the configuration of the continents and seas, and the crowd of living creatures which inhabit them. Every terrestrial or maritime space, clearly limited by some great geographical feature, such as a strait, isthmus, mountain-chain, or plateau, every district distinct from the countries bordering upon it by the nature of the soil, and especially by the climate, possesses also its peculiar fauna, having but a relatively small number of representatives in common with those of other regions. The French plains which stretch to the north of the Pyrenees, and the Spanish valleys of the tributaries of the Ebro, contrast with each other in a sufficiently striking manner, both by certain species of animals and by their vegetation and the general aspect of all nature. Similarly, the difference is very great for the living organisms as well as for the soil on the two slopes of the Alps; in France, in the stony and desolate basins of the Drac, the Durance, and the Verdon; in Italy, on the fertile banks of the Stura, the Po, and the Doire. A narrow isthmus, separating two seas, separates at the same time two worlds of different species. It is thus, that of one hundred and twenty zoophytes, the Mediterranean has only two in common with the Red Sea, and yet the slight sandy barrier of Suez is of relatively recent formation in the immense series of geological ages. The slender isthmus of Central America, which lies between the Pacific and Atlantic Oceans, is an insurmountable barrier to the two faunas, and the waters separated by a distance of a few miles only, are inhabited by totally different species; there scarcely exists, Darwin tells us, a single fish, mollusc, or cetacean, which is common to the two oceans. Even the course of the Amazons River serves as a limit to multitudes of species; there are birds which never venture to cross it, and whose area of habitation is strictly limited either to the right or left bank.

In consequence of the great diversity of the present conditions of climate, soil, and food, in consequence also of the infinite multitude of causes which, in the earlier ages, may have favoured or hindered the development of the species engaged in the struggle for existence, the areas occupied by different animals are most unequal in extent. There are cetaceæ, swimming birds, and echinoderms, which live in all the seas, and gnats, which fly in clouds over the marshes of all the continents; on the other hand, certain species are only found in a very limited region. Some reptiles are peculiar to a single district of the Rocky Mountains or the plateau of Utah; a certain humming-bird has been discovered in only one valley of the Andes; every lofty volcano of Ecuador, as Pichincha, Chimborazo, and

Carahuirazo, is a separate world, having its own special fauna. In the immense Amazons River three species of a fish called arias are found only to the west of the island of Marajo, in a space of scarcely two leagues, at the place where the mingling of the mud raised by the conflict of the sea and river takes place.

Besides, the different areas of habitation change incessantly during the course of ages according to the modifications of soil and climate. Man, too, who is also a geological agent, and one of the most active, has taken an enormous part, either directly or indirectly, in the distribution of animals ; but apart from this decided influence due to human intervention, it is certain that all the variations of the surrounding circumstances produce corresponding variations in the distribution of species. If cold or heat increase in a country, the winds become stronger or weaker, the rains increase or diminish ; or if the soil be renewed by alluvium, or saturated with salt by an irruption of the sea, or if a marsh be formed or dried up, a number of species of animals will advance or retreat to find conditions of existence which are more favourable to them, and also to seek food which suits them. Thus various birds of the upper Engadine have established themselves in the lower valleys, and the magpie has even entirely quitted the district. This is a phenomenon which all naturalists have observed : they have even ascertained many apparently inexplicable examples of migrations, so imperceptible to man have been the modifications of circumstances which have produced these changes in the areas. Thus the whales ceased to visit the Faröe Islands for 22 years, from 1754 to 1776 ; in Sweden a number of species have completely disappeared from the country, and have then returned like exiles re-entering their native land, to inhabit again the country of their ancestors. Nor is this all : not only may animals enlarge or restrict their areas of habitation, but they may even completely disappear ; and zoological history, hardly commenced a few centuries ago, already has to relate the extinction of several species. On the other hand, new creatures take the place of those that have departed, and during the succession of ages the fauna is renewed by the formation of varieties, which become more and more constant, and at length present all the characters of species. How otherwise can we explain the remarkable fauna described by Darwin, which belongs especially to the Galapagos Islands, and is neither found in the archipelagos of the South Sea nor on the nearest continents ?

CHAPTER LXI.

GREAT TERRESTRIAL FAUNAS.—HOMOIOZOIC ZONES.—THE FAUNA OF THE SEA-SHORE.

EVERY district distinguished from those that surround it by a certain number of animal forms, has thereby a special fauna; but naturalists usually take this word fauna in a more general sense, and apply it to a collection of species inhabiting a vast geographical region, beyond which the majority of forms are completely changed. For the rest, as might be expected, savants are far from agreeing on the limits of these regions, for these frontiers have no real existence, and in the multitude of living creatures, whose areas of habitation mingle with and intersect each other, there are several which belong at the same time to many districts. Schmarda, one of the most eminent classifying zoologists, enumerates 21 great terrestrial faunas, including those of Madagascar, the Sunda Islands, and Oceania. These various zoological provinces, each one of which possesses only a small number of species in common with the neighbouring provinces, have still many points of resemblance with each other, owing to the multitude of animals which approach each other in form and structure, and fulfil analogous functions in nature. Those species, which in the fauna of a continent take the place occupied in a different country by other animal forms, are termed scientifically representatives. Thus the camels of the Old World are replaced in America by lamas and vicunas; the horses of Asia have the zebras as relations in South Africa; the ostriches of the Sahara are represented in Australia by emus, and in the Argentine pampas by rheas. In this respect the animal world presents the same harmonies as the vegetable world.

The greatest analogy between the two organic series is found also in their order of distribution over the circumference of the globe. All the circumpolar regions of the northern hemisphere in America, in Europe, and in Asia, are inhabited by identical species, or at least present a great appearance of relationship to each other; the same flora and the same fauna occupy the extremities of the continents; but towards the south, in proportion as the lines of latitude enlarge their circles, and the Old and New World withdraw from each other, the living creatures that people them, animals and plants, differ more and more. The number of organisms common to the lands separated by the Atlantic and the Pacific Oceans gradually diminishes, and in the tropical regions the contrast between them is complete. At the same time, animal and vegetable species become more and more numerous in the direction from the pole to the equator. In Spitzbergen, M. Charles Martins found only four terrestrial mammals; 22 species of birds, all of them being

migratory with one single exception, flying beyond the mountains of this archipelago; 10 sorts of fish inhabit its coasts, while the lower orders of animals are represented by only a very small number of forms: only 23 insects and 15 molluscs have been discovered there. To the south of the northern regions the number of species, genera, and families is multiplied tenfold or even a hundredfold; and in the equatorial countries, where vegetation exhibits all its luxuriance and wealth, the fauna shows also a marvellous variety of organisms, and its types are of the most beautiful and dazzling colours. A single naturalist, Bates, after a stay of eleven years on the banks of the Amazons, brought back a zoological collection of 14,712 animals, 8000 of which were new to science. How many must still remain to be discovered, especially among the insects and Annulosæ. According to Agassiz, the Amazons alone possesses three times as many different fish as the immense basin of the Atlantic.

It is true that if the countries nearest the pole are poor in species, these species themselves are for the most part represented in immense numbers. On all the promontories and in all the fjords of the Hebrides, the Shetland and Faröe Islands, Norway, Spitzbergen, and Nova Zemlia, the shelves of rock, similar to the stages of an amphitheatre, are occupied, far as eye can see, by ranks of birds crowded together like an army of soldiers. When these prodigious flocks of birds set off in search of prey they rise like clouds, and man has only to shoot at hazard in order to strike down his victims, unless, armed with a stick, he prefers to despatch the females, which, screaming with rage, remain devotedly covering their broods.

The oceanic faunas must necessarily present a greater regularity in their distribution than the terrestrial faunas, for they are not liable to such changes in physical conditions as affect the surface of the land. The sea is not, like the land, full of obstacles which check the distribution of animals, and modify, in various ways, the configuration of their domain. Thus the limits of each great maritime fauna are precisely those of the basin where this fauna is developed; to the east and west they are the shores of the continents; to the north and south they are the different climates which arrest the species, and cause them to be succeeded by other animal forms.

Edward Forbes was the first who attempted to draw a map of the distribution of living organisms in the seas, and since then the general results which he indicated have been confirmed in great part by the various savants who have followed him in this way. Each region or maritime province is characterized by species which may serve as representatives of all the other organisms of the province, and which attain their greatest development in these parts. From all sides of the central zone, where the fauna peculiar to the province shows itself in all its richness, the species go on diminishing by degrees towards the other regions, and are finally replaced by the prevailing species which in this portion of the sea constitute the bulk of the marine population. Forbes compares the domain of each of these fauna to a nebula, the luminous points of which, united in the centre in a brilliant mass, become less and less numerous as they diverge from the centre, and on the circumference constitute nothing more than scattered traces. The oceanic fauna, consisting as they do of a series of zoological nebulæ, do not, however, differ in this respect from the continental fauna; but, owing to the facilities for migration afforded by the sea to free-swimming animals, the maritime provinces in which any particular species predominates are wider in extent than in an analogous district of *terra firma*. Generally speaking, places situated in the same latitudes are frequented by the same species; a remarkable instance of this fact may be observed

in the Mediterranean, where, from Gibraltar to Alexandria, there is scarcely any difference in the marine fauna. With regard to the limits of these regions common to the same groups, their extent can very seldom be clearly defined, except where ocean currents of different temperatures come into contact. The change from one province to another generally takes place without any sudden transition, for the action of currents, tides, &c., endeavours incessantly to establish an equilibrium in the temperature of the ocean, and prevents any well-defined boundaries of the limits of any forms of life.

It is, nevertheless, necessary to take into consideration every condition which tends to modify the general outlines of each geological province, the form of its sea-coast, the nature of its bed, the rapidity of its currents, the height of its tides, and the saltness of its water.

These various provinces are the extensive regions which Forbes has designated by the name of homoiozoic zones (zones embracing a similar kind of life). They encircle the earth like the climateric zones to which they correspond, and, speaking generally, their limits are formed by the isothermal lines; they also change their position in harmony with these ideal limits, sometimes rising towards the north, and at others curving towards the south.

The great median zone is that of the equator and the tropics, the most important part of which comprises the whole of the Indian Ocean and the central belt of the Pacific, from the coasts of Australia, Borneo, and Japan, to those of Mexico and Columbia. In this region, for the most part, marine animals present the most brilliant colours and varied forms. This, too, is the region where the waters swarm with the greatest number of organisms, and corals and madrepores construct their circular islands, which stud the coasts of Asia as far as the middle of the Southern Ocean. Between equatorial Africa and America this homoiozoic zone is still continued in spite of the interposition of two continents; on the coasts of Florida, the Bermudas, the Antilles, the Guianas, and Brazil, molluscs, echinoderms, and corals, similar to those of other equatorial seas, multiply abundantly; the species are different, but the general types are the same.

To the north of this median zone, which extends round the globe with an average breadth of 3700 miles, there is another encircling zone, which is much narrower and rendered very irregular by the variations of climate which towards the north are produced by winds, maritime currents, and the different conditions of the opposite continental coasts. This northern "circumcentral" zone takes its rise in the Atlantic on the coasts of Georgia and the Carolinas, then spreading out towards the east, it washes the coasts of Marocco and of the Iberian peninsula. Beyond the straits of Gibraltar it embraces the Mediterranean, where there are fisheries for the tunny, sponge, and coral. In this sea the species show a gradual diminution from west to east, and in the enclosed basins in the interior of the continent, the Black Sea, the Caspian, and the Sea of Aral, they are even much less numerous. In the Pacific, this same zone, the limits of which are however scarcely known, stretches from the coasts of the Corea and Japan towards those of California.

The third zone, which is situated about the middle of the temperate latitudes, has received the name (not however a very appropriate one) of the neutral northern zone. Like the last-mentioned zone, it curves round and spreads out across the Atlantic from the coasts of America to those of Europe. It is narrow along the shores of Virginia and Delaware, but it widens out towards the north-east with the Gulf-stream, and embraces all the Celtic seas of the peninsula of Brittany, Ireland, Scotland, and the Shetland Isles. The Baltic Sea and its gulfs are mere depen-

dents on this zone. The great herring fisheries are carried on in this homoiozoic zone.

The most northerly zone, which is characterized by fisheries for cod and other fish of a similar nature, likewise follows the immense curve of the Gulf-stream, and stretches from east to west. Beginning at Cape Cod in the Bay of Fundy, it embraces Iceland and the adjacent seas, and washes the coasts of Norway and Lapland up to North Cape. In the Pacific this zone, known as the northern circumpolar zone, assumes, like the neutral zone, a circular tendency owing to the great current of Japan and the south-west winds, which in this part of the ocean bring about a circuitous movement similar to that of the Gulf-stream.

Lastly, the Arctic Seas are occupied by the polar homoiozoic zone, the extent of which comprises the whole of the spherical cap from the pole to Labrador, the Gulf of Obi, Behring Straits, and Kamchatka. In this region the inhabitants of the sea, generally speaking, are of rather dull colours, and the species are much less numerous than in the southern zones ; but on the other hand, these species are for the most part represented by a great number of individuals.

In the southern hemisphere, the homoiozoic zones follow one another in the same order as in the opposite hemisphere, and exhibit similar transitions between the respective typical species ; but, it must be confessed, the comparative extent of these various zones is very imperfectly ascertained. All we positively know is that to the west of South America, the domain of each of the marine faunas curves round towards the north, carried away, so to speak, by "Humboldt's current," which runs along the coast. For the present, the lines of temperature are the only *data* we have for fixing, somewhat inaccurately, the limits of zones : it will be the task of future explorers to determine them more exactly. It would be equally difficult to state at the present time in what proportion species of marine animals diminish from the equator to the poles. In order to solve this question approximately, it would in the first place be necessary to ascertain the quantity of organic beings contained in the various oceans. All we positively know is, that in the European seas, the species of fish show a diminution of nearly two-thirds in the northern as compared with the southern seas, since in the Mediterranean 444 are met with, while in the Scandinavian seas there are found scarcely 170. Molluscs resist better the influences of climate, for about 300 have been reckoned on the coasts of Sweden and Norway, that is to say, nearly half as many as on the shores of the Mediterranean. During the only voyage of discovery conducted by Captain Wilkes, the American naturalists succeeded in collecting in the tropical waters of the South Sea 829 species of fish, 900 crustaceans, 2000 molluscs, 450 corals, and 300 zoophytes.

In a paper on "The Fauna of the Sea-shore" read before the Royal Institution on January 23rd, 1885, Professor Moseley remarks :—

"The animals inhabiting the littoral region are adapted in most various ways to withstand and endure the special physical conditions which they there encounter —the action of the surf, the retreat of the tides, their numerous enemies. Either they burrow deep in the sand, or cling tight to, or even bore into, the rocks, or develop hard shells or skeletons, or protect themselves by other modifications. Probably all hard shells and skeletons of marine invertebrates have thus originated in the littoral zone for purposes such as these. It is found that these hard structures tend to degenerate and disappear both in the pelagic and deep-sea regions.

"It is a most remarkable fact that almost all these shore animals in their early

development from the egg pass through free-swimming larval stages, which are closely alike in form for very widely different zoological groups. As a familiar example may be taken the case of the common oyster. The egg of the oyster develops into a peculiar free-swimming larva known as a Trochosphere. It is globular in form and divided by a transverse band of cilia into a smaller anterior and larger posterior area. The mouth opens just behind the ciliated band. The larva swims actively by means of its cilia. After a time it develops a pair of shells, and becomes metamorphosed into an oyster, and attaches itself immovably by one of its shells to the sea-bottom. Its shells increase in size and thickness, and form a protection against its enemies. This same trochosphere larva is common to a very large number of mollusca of all varieties and shapes in the adult condition, and an essentially similar trochosphere is common to a large number of annelids. It is most remarkable that there should be so close a resemblance between the larva of two adult forms so widely different in all respects as an oyster and a worm. An old explanation of such facts was that such actively moving larvæ were contrivances for procuring the wide diffusion of sedentary or less active adult forms, which might thus be conceived as of later origin than the forms themselves. But if this were the case, it is inconceivable that having arisen from so widely different starting-points, the larvæ should have attained so closely similar a structure. The only real explanation of the matter is that the common larval form represents a common ancestor, from which the various adult forms, in the existence of which it is now only a phase, diverged. There was thus a common freely-swimming ancestor of the annelids and mollusca, and it seems probable that the entire littoral fauna must have been derived originally in remote antiquity from small primitive and simply organised free-swimming ancestors. All evidence seems further to point to the conclusion that the primitive ancestors of all plants were also free-swimming. The free-swimming ancestral representatives of life no doubt partly inhabited the open sea, leading a pelagic existence, partly swarmed in sheltered bays and pools on the coasts, as the larvæ of the littoral animals do now. The free-swimming plants gradually produced attached descendants, which colonised the shores, and the animals, finding there a supply of food, gradually adapted themselves to the more complicated conditions of shore life. The late Professor Balfour, in his far-famed work on "Embryology," in discussing the character of larvæ of the kind under consideration, spoke of them as possibly reproducing the characters of some ancestral forms which may have existed when all marine animals were free-swimming.

"A peculiar instance in which there can be but little doubt, is that of the common barnacles. These, in the adult condition, are firmly fixed to supports of various kinds, and withstand the most violent action of the surf. The common acorn barnacles cover the most exposed bare rocks of our coasts, where the waves are heaviest and nothing else can live. They have developed the stoutest of shells to protect themselves. In the young larval condition, however, they are actively free-swimming larvæ of typical crustacean structure, evidently adapted for pelagic existence, and to be found in swarms at the sea-surface, actively engaged in it. They attach themselves, and become immovably adherent and sedentary, and invested by a shell. There can be no doubt in this case that the locomotive larva represents the ancestral form, for allied crustacea still exist in abundance as adults.

"A most important instance is that of the echinoderms, the adults of the various groups of which, the sea-urchins, starfish, brittle stars, holothurians, and crinoids are most widely different in form, and adapted in most various ways to

shore life. Yet these all pass through free-swimming larval stages which are most remarkably alike. Supposing the adult forms to have been antecedent, it is quite impossible that a series of larvæ could have been developed independently from starfish, echini, holothurians, and brittle stars, and have attained this remarkable coincidence of structure. This common larval form must represent the ancestral condition, the free-swimming pelagic ancestor from which the echinoderms have sprung.

"The fixed and inert sponges are developed from free-swimming ciliated larvæ, and Professor W. J. Sollas has observed that the young larvæ of the sponge *Oscarella lobularis* are retained longer within the parent in the case of specimens occurring on the coast of Brittany than in that of specimens found in the Mediterranean. He attributes this difference to the influence of the quieter sea and absence of tides in the latter case. The larvæ have come to be longer retained where the risk of their loss by current and tide is greater. By the gradual action of similar influences, no doubt, the loss of larval stages in so many instances has come about. It is probable that there is a special tendency to such loss in the case of deep-sea animals. Hoek has recorded the loss of the nauplius stage as a free-swimming one in the case of a deep-sea scapellum from a depth of 506 fathoms. One of the best examples of the special adaptation by modification of animals sprung from pelagic ancestors for littoral existence is that of the madreporarian corals, the far-famed builders of reefs. Each coral colony is sprung from a locomotive planula larva, swimming by means of cilia. The larva attaches itself, and develops into a polyp, and acquires a hard skeleton, and by budding produces a large colonial stock. The massive stocks thus formed and strengthened form reefs which are barriers to the waves. They flourish in the water churned by themselves into surf, and thus specially aërated and fitted for their respiration, and between their branches and interstices they sift out the fine pelagic animals on which they feed from the surface water. Probably the advantage thus gained is the cause of their assumption of the colonial form and development of their stout and massive skeletons. Possibly this is the reason why scarcely any colonial madreporaria occur in deep water, although other colonial animals are abundant in the depths.

"The origin of the vertebrata is a complex question, but they are probably sprung from a very simple free-swimming ancestor, as is shown by the survival of a simple ciliated gastrula as an early stage in the developmental history of Amphioxus. An exactly similar developmental stage precedes the trochosphere form in the oyster, and the characteristic larvæ in the case of the echinoderms, and occurs as an early stage in a wide range of other forms. From this ciliated gastrula develops Amphioxus, one of the most interesting components of the fauna of the coasts, one of the most primitive of vertebrates now existing. The ascidians, which are in the adult condition as inhabitants of the coasts, mere inert sacs, extreme instances of degeneration, are derived from free-swimming larvæ of pelagic habits which show distinct vertebrate structure and have myelonic eyes, which, as Professor Lankester has pointed out, could only have originated in an animal of pelagic habits. The ascidians, before reaching their vertebrate larva stage, pass through a gastrula stage like Amphioxus. It is possible, therefore, that their ancestors have twice taken from pelagic to littoral existence, having relinquished the shore for a period after their first experience of it, and returned to it again; whilst some of their close allies, such as appendicularia, have never resought the shore, and consequently have never degenerated to qualify for littoral

life. The peculiar breathing apparatus adopted by the vertebrata occurs nowhere else in the animal kingdom except in the extraordinary worm-like Balanoglossus. The apparatus, as is well known, consists of a series of slits, opening from the exterior at the sides of the fore part of the body directly into the throat, the anterior part of the digestive tract. The water to be respired is taken in at the mouth and ejected through the gill slits. The late researches of Mr. W. Bateson, of Cambridge, have shown that Balanoglossus, besides breathing by gill slits, shows many other remarkable affinities, both in structure and development, with the vertebrata. Now, Balanoglossus, a shore-inhabiting form which lives buried in the sand, is developed from a most remarkable larva known as Tornaria, which is intermediate in form between a trochosphere and a starfish larva. It is quite possible that this extraordinary larva tornaria may point to the former existence of a primitive pelagic ancestor common to the annelids, echinodermata, and vertebrata. Possibly the use of gill slits as a respiratory apparatus first arose in a fhore-inhabiting ancestral form, such as Balanoglossus, and hence their presence at the anterior extremity of the body, that nearest to the surface when the animal is concealed in the sand.

"It appears not impossible that Amphioxus may once have possessed a larval stage somewhat resembling Tornaria, following on its gastrula stage, and has lost it, just as one species of Balanoglossus has lost the Tornaria stage. The developmental history of only one species of Amphioxus is as yet known, and investigation of that of other species may yet reveal something of the kind suggested.

"The littoral zone not only became itself stocked with an immense variety of specially adapted inhabitants, but has given off colonists to the three other faunal regions. The entire terrestrial fauna has sprung from colonists contributed by the littoral zone. Every terrestrial vertebrate, every frog, reptile, bird, and mammal, bears in its early stages of development the gill slits still perforating its throat as in its aquatic ancestor. The tadpole still uses them when young for breathing, though they close up completely in the adult frog and in all the higher vertebrates before birth. In some of the tailed amphibia, like the Axolotl, the breathing is by external gills and also by lungs which are modifications of the air-bladder of fish. In these the gill slits remain open, although they have no longer any respiratory function. It is amusing to watch tame Axolotls when fed in aquariums with large worms. They snap the prey down hurriedly and close their mouths, but usually in a moment or two their throat begins to twitch uncomfortably as if intensely tickled, and one end of the worm appears out of one of the gill slits, and the worm soon wriggles its way out again. Often the Axolotl catches it again by the free end before the other is completely out of the gill slit, and begins another attempt to swallow it, and the process is sometimes repeated several times before actual deglutition is effected. The gill slits are evidently a considerable inconvenience to the Axolotl. The frog is much better off in having them closed, but man himself is not in a position entirely to despise the Axolotl: his lungs are derived from the same source originally, namely, modifications of the air-bladder of a remote aquatic ancestor, an inhabitant of the sea-coast, and they open into the throat just behind the tongue. In man there is a lid to close this opening and a contrivance to pull it under the tongue when swallowing takes place; but every one knows the agony entailed by getting a crumb the wrong way—an accident very much akin to that of the Axolotl, and likewise caused by the use of a single passage for two different purposes—feeding and respiration. At such moments of suffering the naturalist is inclined to turn traitor and long that he had been

produced in accordance with the hypothesis of special creation rather than evolved under the laws of natural selection. The existing arrangement must not be regarded as of inevitable necessity. The vertebrates are the only animals which breathe through their mouths. All other animals have separate passages for respiration and feeding. The common snail has a separate breathing passage completely apart from its mouth, the land crab breathes by openings at the bases of its legs, the scorpion by openings on its abdomen, and the insect by numerous apertures on the sides of its body. None of these animals can, like man, choke themselves.

"Only the pentadactyle vertebrata have adapted themselves completely for terrestrial respiration, but several fish have, by special modification of their gills, become able to remain out of water for almost indefinite periods. Most remarkable amongst these is Periophthalmus, one of the Gobiadæ inhabiting mud flats on the seashore in Australia, Ceylon, Fiji, and other eastern tropical regions. It hops along the mud with the greatest agility, and so fast that it is most difficult to capture, and even refuses to take to the water when driven to it, skipping along its surface, and resting on projecting stones. It even climbs high up the mangrove trees and sits on the branches. All modes of air-breathing are derived by modification from aquatic breathing apparatus, except, perhaps, in the case of the air-breathing tracheata, the insects and their allies, in the ancestor of which, represented by Peripatus, the respiratory tubes or tracheæ were probably first formed as modifications of skin glands.

"Littoral animals of most various kinds have taken from marine to terrestrial life, no doubt by gradual adaptation, owing to exposure by the tides. Crustacea seem to have the greatest power of thus adapting themselves to aërial respiration by slight modification of their gill apparatus, so as to permit it to act as a lung. Nothing is more astonishing to the naturalist in tropical countries than to find large crabs amongst the vegetation far inland and high up mountains. But land crabs are not confined to the tropics; in Japan they may be met with walking across the high roads far inland, and 4000 feet above sea-level. One of the most remarkable instances is that of the cocoanut-climbing crab, *Birgus latro*, which has developed, as Professor Semper has shown, a regular pair of lungs out of the walls of its gill cavities. The animal was originally a hermit crab, but got too large for any shell, and thus developed hard plates on the surface of its body for protection instead. Close allies, but of much smaller size, swarm in some Pacific islands. They always bear shells, and carry them with them when they climb the trees and bushes. I have caught hold of the shell of one of them as it clung to the top of a branch, thinking that it was a land-mollusc, and have been astonished by receiving a sharp nip from a pair of claws.

"The oldest known air-breathing animals, so far as geological evidence goes, are scorpions and insects. An ally of the cockroach and two scorpions have lately been obtained from Silurian strata. The close affinities of the scorpions with the king crabs, and thus with the Trilobites, is a most interesting matter, which has lately been urged by Professor Ray Lankester. He suggests that the lungs, by means of which the scorpions breathe air, are modifications of the gill plates of the king crab, which have become inverted for the purpose. The lung openings of Scorpio correspond with the gill plates of Limulus in position and number. Hence, possibly, the scorpions, and with them the rest of the arachnida, are sprung from ancestral allies of the king crab and the eurypterids, having passed from a littoral to a terrestrial existence.

"It seems possible that birds were originally developed in connection with the sea-coast, and were fish-feeders. The tooth-bearing birds discovered by Professor Marsh, such as Hesperornis and Ichthyornis, were marine aquatic birds. The modern penguins show some remarkable points of affinity to reptiles in the structure of their feet, and probably their embryonic development, when worked out, may throw much light on the past history of birds.

"The fauna of the coast has not only given origin to the terrestrial and fresh-water faunas, it has throughout all time since life originated given additions to the pelagic fauna in return for having received from it its starting-points. It has also received some of these pelagic forms back again to assume a fresh littoral existence. It was in the littoral region that all the primary branches of the zoological family tree were formed. All terrestrial and deep-sea forms have passed through a littoral phase, and amongst the representatives of the littoral fauna the recapitulative history, in the form of series of larval conditions, is most completely retained. It is for this reason that the researches carried on at the marine laboratories on the coasts have yielded in the last few years such brilliant results."

CHAPTER LXII.

DISTRIBUTION OF SPECIES ON THE SLOPES OF MOUNTAINS AND IN THE DEPTHS OF THE SEA.

THE gradation of climate on the slopes and heights of mountains, similarly to their succession in the direction of the poles, brings about, as its necessary consequence, a rapid diminution of animals from the fertile plains at the base to the snowy summits of the mountains. If the naturalist scales some solitary lofty peak in the torrid zone, he will see the number of animal species rapidly diminishing, exactly as if he were travelling towards the temperate regions, and then towards those of the pole. At last, when he reaches the lower limit of perpetual snow, where vegetation almost entirely disappears, there remain but very few representatives of the animal world, and those which still exist in these upper regions are mostly minute beings, like the animalculæ of the snow, and small quadrupeds which bury themselves in the snow, similar to the *vole*, which is met with on the summits of the Alps. Not only do the species gradually diminish on the slope of the mountain, a fact, however, which is easily accounted for by the deficiency of food, the increase of cold, and the rarefaction of the air; but also the animals met with in the upper regions are not the same as those of the lower slopes, and in their form, coat, and habits resemble the animals of the polar zone. The faunas of the Andes and the Alps bear more resemblance to those of Spitzbergen than to those found in the plains at their feet, which are situated at a distance of a few thousand feet. Nevertheless storms, gusts of wind, and waterspouts frequently blend the locally arranged faunas one with another, and as we traverse the snow on the summits, we rarely fail to see the great white surface dotted over with the remains of insects which have been carried up from the valleys by atmospheric currents. Sometimes even a few stray butterflies fly by chance into these gloomy solitudes, where the cold during the night is certain death to them, unless some favourable wind carries them back to the warmth of their native meadows. As far as birds are concerned, numbers of them fly freely up to the loftiest summits. M. Jules Remy has seen myriads of humming-birds flying noisily round the crater of Pichincha; and the traveller, scaling the proudest heights of the Andes, sees far above his head the great condor soaring majestically in the blue sky.

On dry land most animals inhabit districts but slightly elevated above the level of the ocean: following the same rule, a large majority of the inhabitants of the seas, infusoria, annelids, crustaceans, fish, and other creatures, exist in the liquid strata of the surface and in the neighbourhood of coasts. This must be the case, for it is only along the sea-shores that we find rocks which are covered with shells,

caves, and crevices, where the fish take refuge, and also the forests of seaweed, which are used both for shelter and food by multitudes of organic beings; there, too, the rivers convey all the animal and vegetable débris from the mainland, which serves as food for the inhabitants of the sea. Farther out to sea every stray piece of seaweed and every floating mass of the same is also a mustering point, round which a perfect little world lives and moves; even far from the shore and shallow water, life although less stirring in comparison with that of the coast, is nevertheless wonderfully active in the upper strata of the sea, for there the waves take their rise on the surface, and their movements are as necessary to the organic beings of the sea as the breath of the wind is to the life of terrestrial animals; these upper strata are also the portions of the ocean into which the light penetrates. According to the experiments of Wilkes, the rays of light would not descend beyond 82 fathoms, and this point, therefore, would mark the limits, determined by the darkness, habitable by marine animals and vegetables. Therefore the zone of contact where the sea meets the atmosphere, and especially in the vicinity of continents, is where aquatic life swarms in the greatest abundance. On land, the conjunction of several geological strata fertilizes the soil, and consequently promotes a greater degree of activity in the development of the different germs; in the same way, the contact of the three elements, water, wind, and shore, draws organic beings into the surface-strata of the ocean, and thus enfolds the globe as it were in a living envelope.

The shallow parts of the sea, especially in the vicinity of the coasts of Europe and the United States, have been already explored with the greatest possible care by Edward Forbes, in order to point out the approximate depth of the superincumbent layers of flora and fauna. Each of these zones is distinguished by organisms or groups of organisms peculiar to it. They do not, however, with the exception of the upper strata, present any clearly defined boundary; there are, moreover, a great number of genera and sub-genera, which are common either to all the elevations, or to two or three of them.

The first zone, or that of the shore, is limited by the extreme lines of ebb and flow, and according to the height of the tide, is from half a fathom to 11 fathoms in depth; in this stratum a multitude of organisms live and move, because it is in turn occupied both by the water and the air. The second stratum, called the laminarian zone, from a species of seaweed which there throws out its long band-like leaves resembling leathern straps, has a depth of about 16 fathoms below low-water mark. This is the principal habitat of marine plants, fish, molluscs, and crustaceans. Most of the species found here are remarkable for the brilliancy or even splendour of their colours, which they owe to the luminous rays refracted from the surface of the water. The third, or coralline stratum, extends as far as 32 fathoms below the last-mentioned stratum; vertebrate or invertebrate animals are here represented by numerous species, but vegetation begins to be scarce. The fourth stratum of the European seas, which, according to Edward Forbes, has not a depth of more than 110 to 330 fathoms, and beneath which extend the vast solitudes of the uninhabited seas, is without doubt less thickly populated than the body of water above it, into which the light of the sun succeeds in making its way, and the molluscs, crustaceans, and annelids which are found there are for the most part of a sombre hue; but even at this point we have not reached the limit of life.

It is an indisputable fact that marine animals exist at a much greater depth than naturalists until very recently allowed. Although soundings taken at great depths

in the open sea have not at present been very numerous, and though in most cases the sounding line did not bring up any traces of sand or mud from the bed, most savants, relying solely upon this negative evidence, predicated that the lowest depths of the ocean were abiotic spaces, that is to say, absolutely destitute of living organisms. Even when several mariners had obtained proofs to the contrary, many well-known savants, such as Edward Forbes, Godwin-Austen, Agassiz, de la Bèche, were still of opinion that below a certain depth, fixed by some at 165 fathoms and by others at 330 fathoms, all animal or vegetable life was impossible. Each depth of five and a half to six fathoms involving a pressure of water equal to that of an entire atmospheric column, it was thought that the general proximate conditions would be so changed at the bottom of the ocean, that the development of any organisms in these vast depths would be rendered absolutely impossible. It was also a foregone conclusion that living beings could not live under a pressure of hundreds or perhaps thousands of atmospheres. According to an hypothesis which is just as much in opposition to the facts, neither plants nor insects can exist on the high mountains; in the same way, by a kind of polarity, the bed of the ocean was supposed to be nothing but a vast solitude. The hardiest among marine animals would then be the fine coral of the coasts of Norway, the *Lophelia prolifera*, the rose-coloured branches of which are found attached to rocks at a depth of 330 fathoms from the surface.

Nevertheless, since the year 1818, the results of many soundings have contradicted the opinion laid down by most naturalists. In Baffin's Bay, John Ross brought up from the bed of the sea some small crustaceans, annelids, and echinoderms, and in the regions inhabited by these creatures the depth determined by the sounding-line varied from 110 to 1033 fathoms. On the other side of the globe in the Antarctic Seas, James Ross discovered in 1824 some living crustaceans at a depth of 393 fathoms; but this fresh evidence verifying the existence of organisms in the lowest depths of the ocean was ignored like the former. Some time after the soundings made between Ireland and Newfoundland along the "telegraphic *plateau*" brought to the surface a large number of small organisms, foraminifera, polycistina, and diatomacea. Further, the sounding-line brought to light 116 different species of these animalculæ, taken from a depth of 3660 fathoms between the Philippine and Ladrone Islands.

At last, in the voyage of exploration undertaken by McClintock in 1860 across the North Atlantic, Dr. Wallich definitely solved the question by indisputable proofs. At the south-east of Iceland the dredge detached a fragment of a serpula, the flesh of which was still fresh, and some small living shell-fish, from a rock at a depth of 671 fathoms. In addition even to this, another sounding, made at a depth of 1240 fathoms, that is, at a point where the weight of the body of water exceeded 200 atmospheres, brought up several small shell-fish and thirteen star-fish, one of which was not less than four and a half inches in breadth: these animals reached the surface of the water alive, and for a quarter of an hour incessantly worked about their long spike-covered arms; besides, the remains of the foraminiferæ which were found in the digestive organs of the echinoderms allow no doubt as to the fact that these inferior organisms likewise exist at a depth of more than 1200 fathoms in the ocean. Since Dr. Wallich's discovery, Torrell brought up from a depth of 1430 fathoms in the sea of Spitzbergen a crustacean of brilliant colours. The same fact applies to the Mediterranean, for when the telegraphic cable which joins the island of Sardinia to the coast of Genoa was broken, its fragments were found to be covered with polyps and shell-fish, bringing

the wire in some places to the size of a hogshead. Subsequently, the submarine telegraph between Sardinia and Algeria was also broken, and Mr. A. Milne Edwards recognized on a fragment of the cable, fished up from a depth of 1000 to 1500 fathoms, a large number of animals, which must all have existed in the bed of the sea on this wire laid down by human agency; for their forms were moulded round the iron on which they rested, and their soft parts were still in a state of preservation. Among these creatures there were found serpulæ, a species of oyster, a highly coloured pecten shell, and lastly, some polyps which hitherto had not been met with in any part of the Mediterranean, and were thought to exist only in a fossil state. Ehrenberg has shown that luminous animalculæ exist at the bottom of the Gulf of Mexico, and the *Challenger* expedition fished up from great depths a species of *sternoptychides* and other fishes which emitted a phosphorescent light. It may therefore be concluded that at a depth of even thousands of fathoms light is not altogether wanting, and that it shows itself periodically, or even constantly, thus explaining why the eyes of species taken from deep waters are not atrophied like those of fish and insects found in dark caverns.

Thus the depths of the ocean are not a vast desert where the movement of hidden counter-currents is the only evidence of terrestrial life; even in the midst of these regions, where a ray of light never penetrates, there are beings which are born there, which live there, and which there find their graves. Doubtless, most of these beings, like the inhabitants of caverns on *terra firma*, are dressed in a sombre hue; but this is not a zoological law, for those very species which have been discovered at the greatest depths, namely the echinoderms, found by Wallich in the sea of Iceland, and the crustacean taken by Torrell from the bed of the Frozen Sea, present tolerably bright colours. By gradually adapting themselves, either by migration or by the effect of a slight depression of the bed, to their location in these deep waters, these creatures have preserved the specific brilliancy of their colour, which their ancestors doubtless owed to the vivid light with which the superficial strata of the ocean are embued. As far as marine plants are concerned, seaweeds properly so called have not yet been noticed growing at a depth of more than 218 fathoms: the only organisms which could be called vegetable which have been found in the depths of the ocean belong to the primitive order of diatomaceæ.

CHAPTER LXIII.

GEOLOGICAL LABOURS OF CERTAIN ANIMAL SPECIES.—CORAL REEFS AND ISLANDS.

THERE are very few animals which, in order to obtain their prey or to construct their habitations, disturb the ground so forcibly as to leave, either on the surface or in the upper strata of the earth, traces of their work. Rabbits, foxes, "prairie-dogs," and marmots dig out burrows; moles and musk-rats make their way underground, like miners, through long avenues or labyrinthine galleries; white ants construct "high obelisks of clay;" but when the animal builders have left their hidden vaults or visible palaces, they do not long resist the rains, vegetation, and all the other agents of destruction which surround them. Among works directly accomplished by mammals, those which last the longest and may exercise a real influence on the topography of a district, or even its local climate, are the structures made by the beaver; rivulets kept back by these dams are changed into marshes, or perhaps take a different course, and sometimes even become tributaries of another basin. At the time when the forests of Western America were still inhabited by vast tribes of beavers, a large number of watercourses were thus changed, by the trunks of fallen trees, into a succession of pools. Even in our time nearly all the streams which flow to the east of the mountains of British Columbia have been dammed up and changed into marshes. The beavers have themselves destroyed the watercourses which were necessary to their existence. The worm disturbs the ground to more purpose, for although the work done by each individual may amount to very little, the result of the collective labour is nevertheless of the greatest importance; for, as Darwin points out, it is the earthworm which most contributes towards preparing the vegetable soil on which we till.

In the enormous geological changes caused by animal life, the creatures themselves have taken no voluntary part, and if they modify the face of the planet it is solely owing to the accumulation of their débris. The humble sphagnum, and other marsh plants, owing to their innumerable multitude, ultimately spread thick layers of peat over vast plains and even on mountain-slopes, and in the same way the very smallest animalculæ, multiplying by myriads and myriads, at length form immense strata in the outer crust of the earth. One quarter of the town of Berlin is built on loose soil composed of successive generations of these infinitely tiny creatures; at the mouth of the Oder and many other rivers, in the port of Wismar, and on the bar of Pillau, a third, or even a half, of the mud is formed of living species accumulated in incalculable numbers. The mass of animalculæ which every

century is deposited in the port of Pillau must at the very least be estimated at more than a million cubic yards. This mud will some day dry up, and, like schist and sandstone, form solid strata in the plains and mountains of *terra firma*. In the same way diatomacea and foraminifera from the bottom of the ocean, and corals from the superficial strata of the sea, are constantly at work building up geological rocks, like those which were formed by species in former ages, and at the present time constituting parts of the mainland. By their constant work of assimilation, polycistina, globigerinæ, sponges, madrepores, and other workers of the sea, collect the carbonic acid, lime, and silex brought down by the rivers, and rebuild the earth slowly with these materials. Whilst watercourses are gradually wearing away the foundations of mountains and demolishing them particle by particle, the inhabitants of the sea are engaged in laying the foundations of a new world. Some idea may be formed of the immense part played in the history of our planet by marine organisms, when we take into consideration the production of the calcareous formations which cover so large a portion of the earth's surface. Burmeister rightly remarked that whatever may have been the origin of limestone, dolomite, and chalk, it is quite certain that all the rocks of this mineral composition have been "eaten and digested" by animalcules similar to those met with in the ocean at the present time. The foraminifera in the bed of the North Atlantic deposit calcareous matter exactly like that found in our present mountains; new oolitic rocks are formed, composed entirely of small *orbulina universa*.

The best known, if not the most active, of these workers of the sea, these "world-builders," are the zoophytes (*Zoantharia*), numbering some hundreds of species, the accumulated débris of which forms vast tracts of land in the South Sea and the tropical Atlantic. The corals of more temperate zones do not increase in multitudes sufficiently numerous to form banks of rock to any great extent. Only those waters of which the temperature is at least 66° F., that is, within an equatorial zone about 50 degrees in breadth, form the scene of operation in which these enormous crowds of workmen can live and multiply, and, by the elaboration of the calcareous matter contained in solution in the body of water, can gradually cause dry land to rise up from the bed of the ocean. The working polyps, most of which belong to the madrepore family, cannot live in any seas which are crossed by cold currents. There is not a single coral reef to be seen all along the western coasts of South America, which, although warmed by a tropical sun, are also washed by the cool waters coming from the South Pole. The gradual increase of cold in the deeper strata of the sea is also probably the reason why the coral-builders live only at a slight depth below the surface; below 25 fathoms the dredge does not discover a single specimen.

In certain parts of the South Sea, multitudes of these animated flowers, the different varieties of which shine with the most brilliant colours, give to the surface of the water in its shallower parts the appearance of a field studded with glittering flowers. The colour of the calcareous masses produced by successive generations of madrepores is generally of a dead white. The reefs constructed by the meandrines rise up in conical protuberances, which are covered with winding lines like the circumvolutions of a lobe of the brain; the edifices built by porites spread out in large regular strata, while those of other creatures are composed of cavities bristling with points, sometimes even assuming the appearance of petrified brushwood. When the reefs have gradually emerged from the sea, and have been left by the colonies of animals which inhabited them, the different species of coral forming the rocks may often be recognised; but in many cases the stems and

branches of coral have been broken into so many fragments, and so intimately mixed up with the débris of shell-fish, that no trace of the original fabric can be discerned; the rocky mass, which is entirely an animal production, appears quite as destitute of débris of any regular form as beds of sand. Every trace of the life which has produced the islands, and is still at work on their outer edges, has completely disappeared. Having undergone this change, the calcareous rock, which, moreover, bears an exact resemblance to strata of the same origin which were deposited during ancient geological periods, is often very compact, and sometimes even partially crystalline, like a sort of marble.

In reefs still inhabited by living creatures the most active corals, such as the meandrines and porites, are those which occupy the external portions of the rocks which are exposed to all the force of the waves; their calcareous bulwarks, which break the forces of the tides and the surf, protect the more delicate species which take shelter in the channels and lagunes inside the reefs. The banks are not, however, entirely composed of polyps; shell-fish abound in great variety in all the little pools among the rocks, and augment with their remains the thickness of the mass; echinoderms fill up with their spikes all its crevices; and lastly, myriads and myriads of foraminifera, forming a lesser world living in this world of corals, swarm in every wave which washes the reef. In many parts of the South Seas, especially on the great barrier round Australia, the sand is entirely composed of whitish discs of these marine animals. All this immense swarm of animation, which may be compared to a chemical apparatus of vast dimensions, is

Fig. 174.—Profile of a Coral Reef (after Darwin).

incessantly engaged in assimilating the calcareous salts which have been carried away from the earth by the sea-water, and is storing them up for the formation of future continents.

In spots where the subterranean forces, which are at work in the depths of the earth, are upheaving the bed of the seas, the reefs naturally emerge in a period more or less prolonged according to the power which impels them, and, during the course of ages, gradually rise above the sea with the islands of which they have laid the foundations. Nevertheless, the madreporic rocks also ultimately emerge from the water in places where a gentle movement of depression is gradually swallowing up the former land. Many an island which reared its summit high above the ocean has long since disappeared, and ships now cast anchor in the very place where its crest was swallowed up; but round the former sea-coasts, which are at the present time covered by the waves, there is now spread out an annular belt of islets and reefs rising out of the water like a living wall. These extraordinary ranges of narrow reefs, disposed in a circular or oval form in the middle of the sea, constitute those atolls the formation of which has been so well explained by Darwin. According to Dana the larger coral islands of the Pacific are 290 in number, and together comprehend an area of 60,000 square miles, that is, about an eighth part of the ground rising above the surface of this ocean. As far as the smaller islands of the same origin are concerned, no attempt has yet been made to count them. The king of the Maldives, a name signifying "innu-

merable islands," can, without any exaggeration, assume the title of Sultan of Thirty Atolls and Eleven Thousand Islands.

Since 1702, when Strahan discovered the marvellous productions of the madrepores, every navigator tells us how the structures brought up by the polyps to the level of the water may gradually be converted into dry land, and become covered with vegetation. The waves break in pieces the projecting stems, and, lifting up the looser fragments of coral, drive them onwards to the highest point of the reef. There, by degrees, they form a bank of débris on which the breakers beat and bring from the open sea sand, broken shells, and the remains of the innumerable organisms which swarm in the ocean. Enriched by these additions brought to them by the waves, the calcareous banks become covered here and there with a thin layer of vegetable soil, where sooner or later some seed germinates which has been

Fig 175.—Roadstead of Papeïti (Island of Tahiti).

carried away by the current as it washed the coast of some distant land. A few land plants embellish with their verdure the grey and monotonous coast; after a time trees take root there; then insects and worms, carried along on drift-wood as if on rafts, begin to populate the incipient groves; birds resort thither to hide their nests among the foliage; and at last it often happens that some fishing party, attracted from afar by the beauty of the site, come and take possession of the new land, and build their huts on the edge of a spring which has been gradually formed in some cavity by the subterranean filtering of the rain-water. Such has been the history of hundreds and thousands of the islands scattered over the Pacific Ocean and the Indian Sea. Some of them have been known to take their rise during the course of the present century. Thus the island of Bikri, in the atoll of Ebon, had not reached the surface of the water in 1825; but in 1860 it had already become a

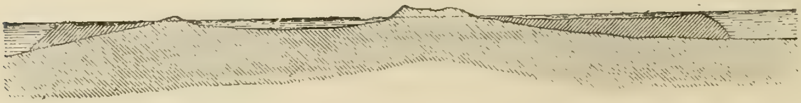
dry rock with an area of about four roods, and some pandanus, sown there by the waves, were growing in the sand on the shore. Other islands, formerly separated from each other, are now united so as to form a crescent-shaped tract of land, and

Fig. 176.—Gambier Island.

the former divisions may still be recognized by their rocks, which are either bare or covered with a scanty vegetation.

Generally speaking, the section of the ring which is turned towards the point of the compass whence the wind most frequently blows is that which presents the greatest extent of dry land or even a complete half circle, for the animalculæ building the reef take a delight in the beating of the surf. There are, however,

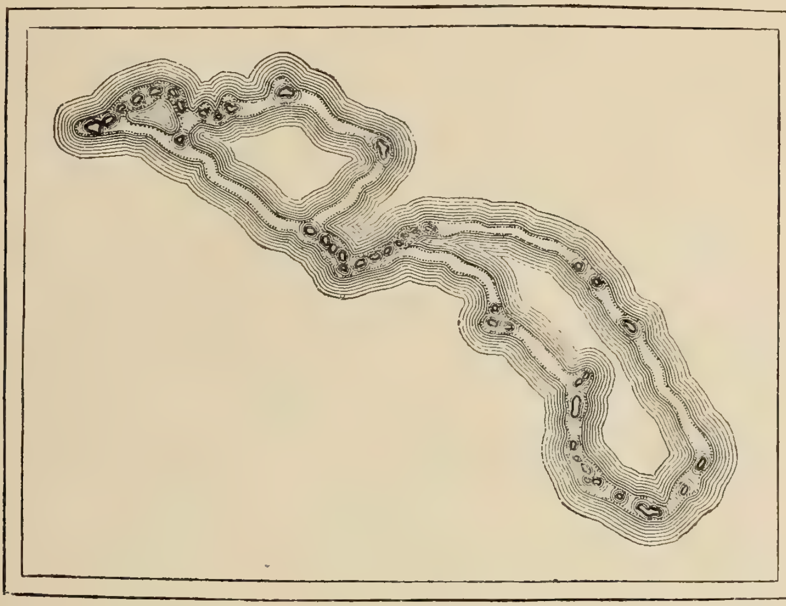
Fig. 177.—Profile of Gambier Island.



certain archipelagos, like that of the Marshall Isles, where islands continuously increase on the very side of the atoll which is least beaten by the waves. This fact is accounted for by the violence of the north-east trade-wind, which, during six months in the year carries from the eastern to the western reefs all the broken

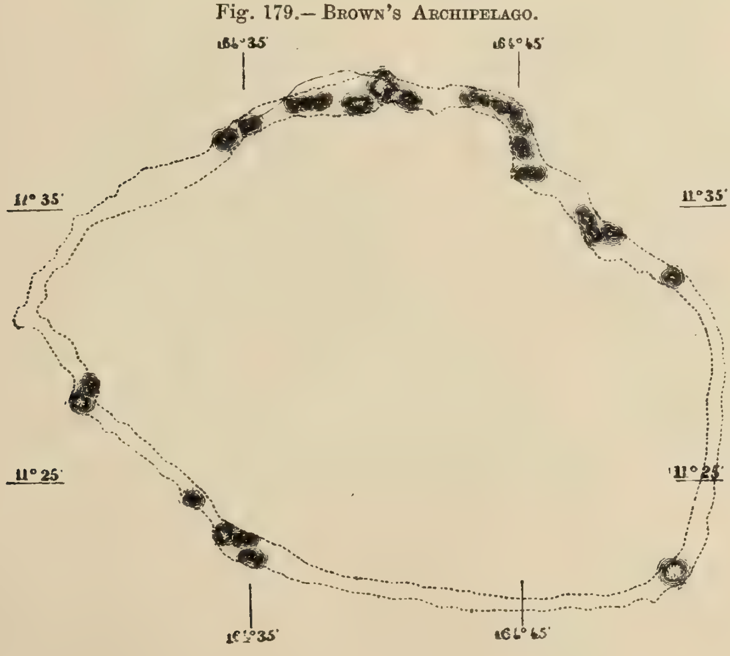
pieces and drifting matter, and thus constructs an artificial bank on the least populated side of the atoll.

Fig. 178.—Atoll of Menchikoff.



Still the appearance of reefs differs considerably according to the activity of the coral insects and the various physical conditions of the ground on which they

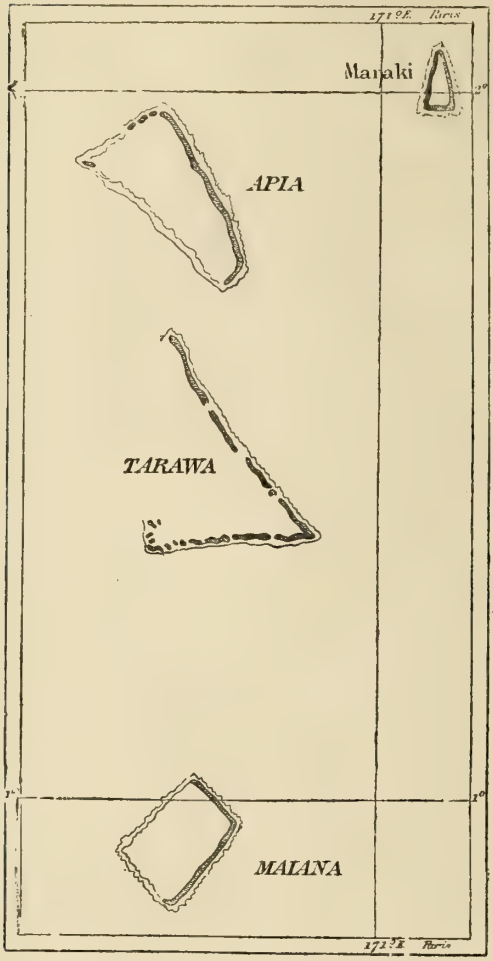
Fig. 179.—Brown's Archipelago.



erect their structures. All round a great number of islands, Tahiti being an example of this class, the reefs of madrepores fringe the shores like the shoals on

the rocky coasts of Brittany, and between *terra firma* and the belt of reefs properly so called there is little more than a narrow canal, through which vessels make their way with difficulty; but being protected against the surf of the open sea, they are navigated in safety. Other islands, Gambier and Vanikoro for instance, are encircled at some little distance by an almost complete belt of rocks of a tolerably regular formation. In these cases, however, the central isle has disappeared and its place is taken by a lagune which is surrounded on all sides by the atoll with a circle of reefs and breakers. Some atolls are single, like the famous Keeling atoll, which has become celebrated through Darwin's description; others are double, like that of Menchikoff; others again are multiple, innumerable so to speak, like those marvellous agglomerations of the Maldives, where each reef is an atoll in miniature, and, with other reefs of similar shape, constitutes a larger atoll; and this larger atoll is but a link in the immense chain of an atoll having a circumference of 62 miles. We also find in the sea many groups of scattered islets, which do not seem to differ from the dispersed archipelagoes of seas in the temperate zone, and would not be recognized as fragments of some large annular islands, were it not that a circle of shallow water shows that these islets are nothing but the emerged points of a submarine atoll. As an example of this formation we may mention "Brown's Archipelago." Lastly, certain coral islands, especially those in a certain part of the Kingsmill archipelago, assume the shapes of almost perfectly regular triangles and squares. It is difficult to explain this strange arrangement, which doubtless proceeds from the collision of oceanic currents.

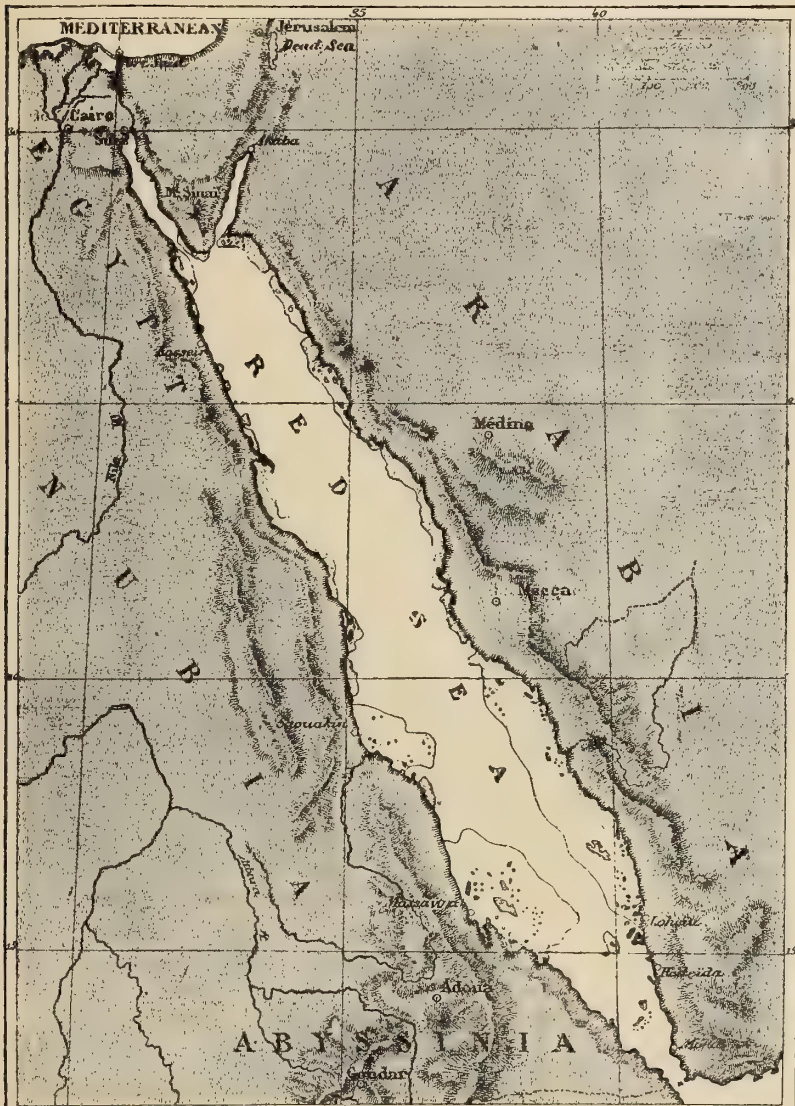
Fig. 180.—Part of the Kingsmill Group, after Dana.



By comparing on several occasions the exact height of the coral reefs situated at the foot of the forts on the rocks of the coast of Florida, Agassiz found that the average growth must be computed at from seven to eleven inches in a century. Thus the madrepores appear to take a long time over their work, and very small changes in the comparative distribution of land and sea occupy a long succession of ages in their accomplishment; nevertheless these innumerable multitudes of animals, engaged as they are in the incessant construction of their calcareous edifices, are of the greatest importance in the history of the world. They are at work on almost all the shallows and coasts of the Red Sea, the Pacific, and the Indian Ocean, that is to say, on a total extent of coast-line of several tens of

thousands of miles. It is not therefore a mere figure of speech when geographers designate corals as the builders up of future continents. Between Australia and New Guinea, in that part of the ocean which has received the special name of "the Coral Sea," countless myriads of coral insects are employed in concert in no less a work than the reconstruction of that sunken portion of the world which, in

Fig. 181.—The Red Sea and its Coral Reefs.



the southern hemisphere, once tended to balance the mighty mass of Asia. The continuous line of reefs which stretches outside the coasts of Queensland and the peninsula of Cape York is not less than 931 miles in length; towards the entrance of Torres Strait this coral wall, appropriately named the *Great Barrier*, is changed into a regular dike, the openings of which are known only to the most experienced pilots. For a space of about 310 miles any access to the coast of Australia and

the Strait of Torres is completely shut out by this winding rampart of madreporic rocks; and beyond this obstacle ships sailing towards the Sunda Isles have still a number of reefs to round; there is also a complete labyrinth of narrow canals which must be carefully followed ere they reach the open sea. We might justly say that an isthmus of rocks, 124 miles in breadth, has always united the Australian continent to the large island of New Guinea.

In the Atlantic Ocean the only coral structures of any importance are to be found at the outlet of the Gulf of Mexico. The peninsula of Florida, a low and marshy tract of country in which the only hills are merely mounds of sand raised by the wind, is entirely composed of coral débris and calcareous sand. This enormous territory, not less than 78,000 square miles in extent, reckoning up to the line where the continental highlands begin, is the work of polyps. Taking for the foundation of their edifices a long strip of sand, which was probably formed between the waters of the Gulf-stream and those of the main sea, the animalculæ, in the first place, built their structures up to the water's edge. The waves afterwards

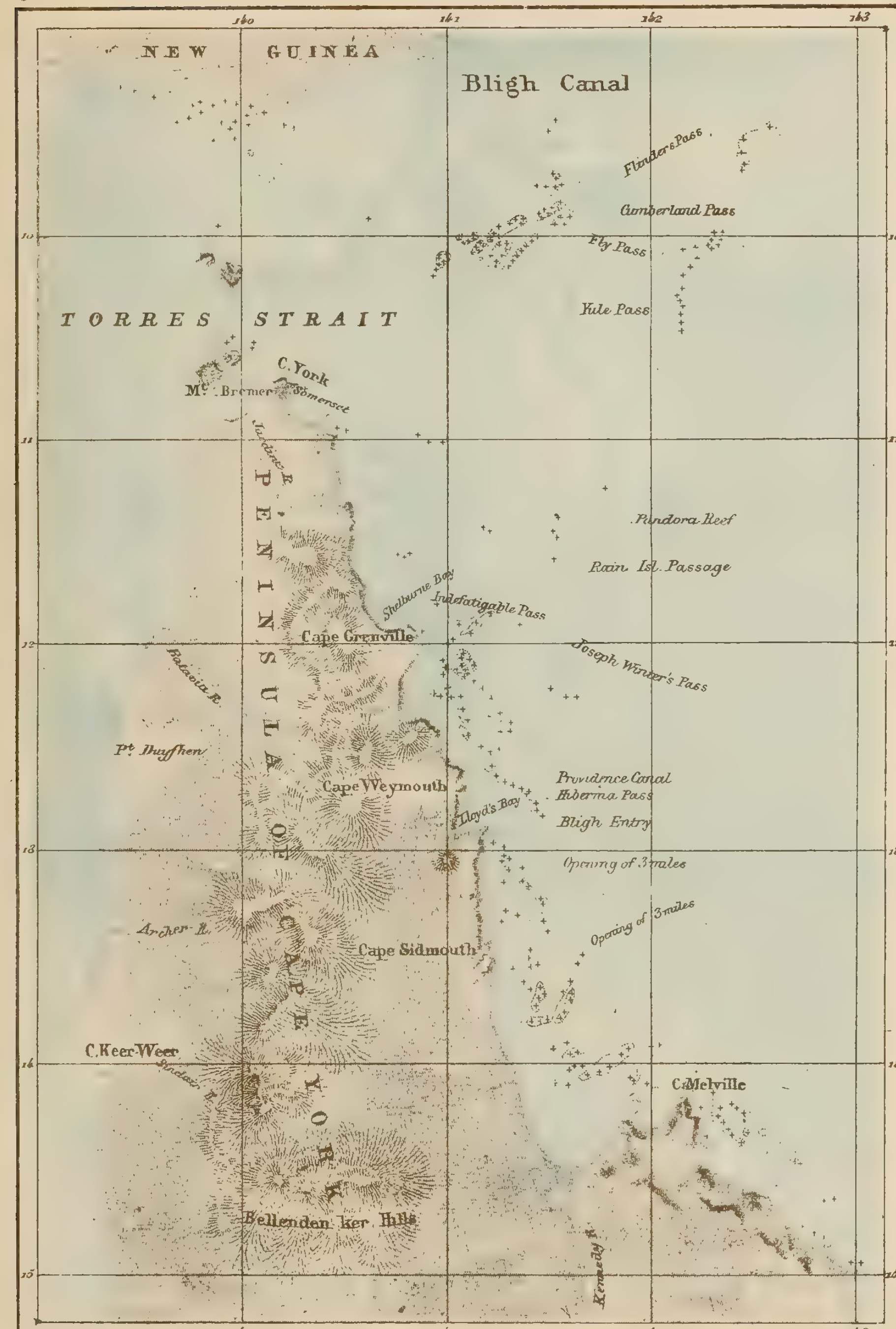
Fig. 182.—The Keys of Florida.

destroyed all these reefs, and having reduced them to sand, cemented them into one solid mass in combination with all the débris cast up by the sea. It must however be confessed that the corals have taken their time over this immense undertaking. According to T. Sterry Hunt, the period which the polyps must have required for raising the reefs of Florida from east to west would be at least 864,000 years, and the development of the peninsula from north to south must necessarily have occupied a period of not less than 5,400,000 years. Florida has now ceased to increase towards the east; for on this side its shores are bordered by the deep water of the Gulf-stream, and polyps, as they work only in shallow water, cannot live there. The peninsula increases in extent only on its western and southern coasts.

As has been shown by the explorations of Agassiz and several officers of the American navy, the construction of the southern point of Florida presents the

'Ocean. PL. XXIII.

THE GREAT BARRIER REEF
AND TORRES STRAITS.



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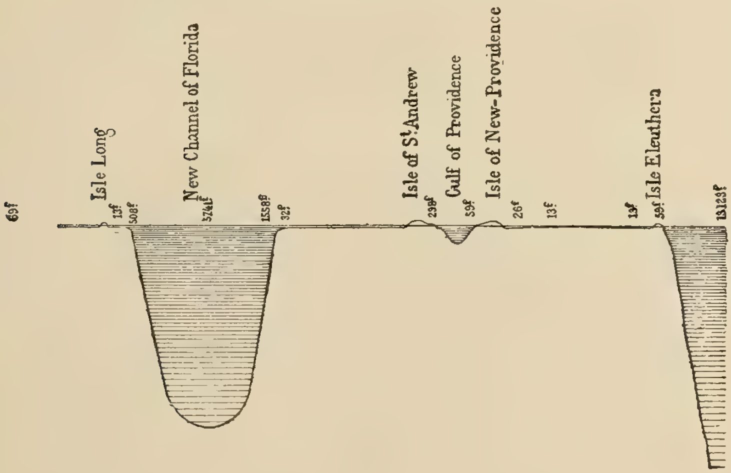
remarkable phenomenon of concentric coasts. A long way out in the sea, and even on the very edge of the bed which is filled by the waters of the Gulf-stream before

Fig. 183.—The Bahama Archipelago.

they make their way through the Bahama channel, there extends a semicircular range of rocks, which, here and there, reach the surface of the water, and along almost their whole extent are still in course of construction; this is the future

Fig. 184.—Cross-section of the Bahama Islands.

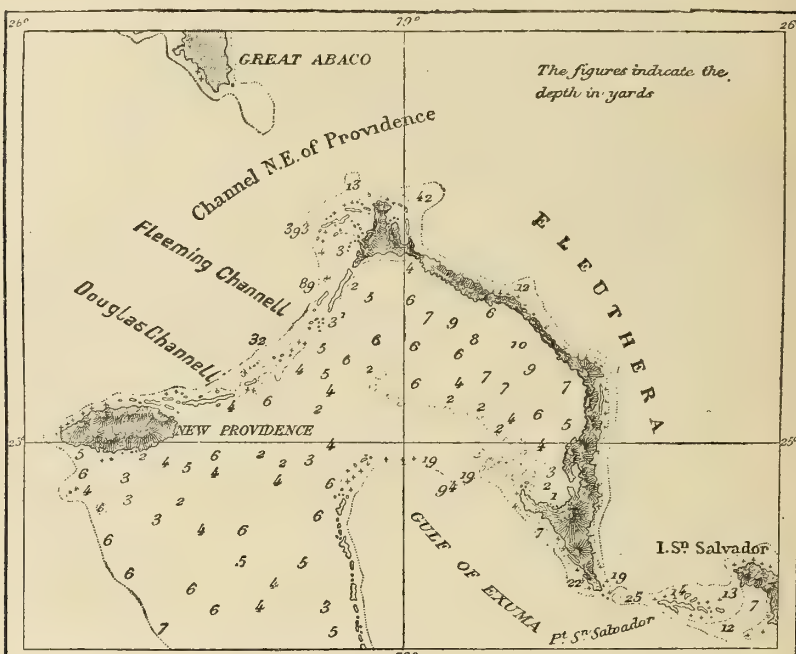


coast of the peninsula. Inside this first range of reefs, which is only indicated by breakers and a few rocks, there extends a long curve of *keys* or *cayos*, composed of

islands, islets, and rocks, forming an almost continuous line. This constitutes the true coast of the peninsula, and on its extreme point has been erected, as if to keep watch, the great fort of Key-west, one of the most important military depôts and maritime and commercial stations in the world. Behind this sheltering range of keys, at an average distance of nine miles, stretches out the regular coast, composed, like the external reefs, of coralline débris; then, farther inland, the geologist finds again ancient banks separated from each other by marshes and tracts of low lands. These were the reefs which two or three hundred centuries ago were beaten by the waves, at an epoch when the present coast was nothing more than a succession of islets scarcely level with the water.

The Bahama Islands, which are also structures erected by coral insects in the shallow parts of the sea, present, like Florida, a sort of façade which at the east is

Fig. 185.—The Islands of Eleuthera and New Providence.



suddenly cut off by the depths of the open sea; the western side, in the still waters of the great banks, is the spot where the organic débris and mud accumulate which, sooner or later, will form the largest archipelago in the West Indies. On the side towards the main sea the islands are developed into a very elongated arc of a circle, and uniformly present the appearance of incomplete atolls; madrepores, astreas, and caryophyllæ, which delight in working when washed by the huge waves of the open sea, cannot, in fact, complete their structures except upon the side which is washed by the surf, and therefore do not build annular walls like those which rise amid the waters of the Pacific.

CHAPTER LXIV.

THE INFLUENCE OF NATURE ON THE DESTINY OF MANKIND.—ANTIQUITY OF THE HUMAN RACE ON THE EARTH.—MONOGENISTS AND POLYGENISTS.—FUSION AND CLASSIFICATION OF HUMAN RACES.

MAN does not only live upon the surface of the soil, he has also sprung from it; he is its son, as we learn from the mythologies of all the nations. We are of the dust, the water, and organised air, and whether we may have sprung from the slime of the Nile, whether we may have been formed from the red earth of the Euphrates or the sacred alluvium of the Ganges, we are none the less the children of the "beneficent mother," like the trees of the forest and the reeds of the rivers. She it is from whom we derive our substance; she nourishes us with her mother's-milk, she furnishes air to our lungs, and, in fact, supplies us with that wherein "we live, move, and have our being." It must therefore necessarily be the case, that those special forms of the earth, with which their flora and fauna harmonize so wonderfully, should be likewise reflected in the vital phenomena of that one fauna which we call mankind.

All the organisms which exist on the surface of the earth may, it is true, act in opposition to nature and infringe the limit fixed by the various climates they have been used to according to the intensity of their vital energy. Plants and animals are ever seeking to enlarge their domain, and, species by species, carry on an incessant struggle for the possession of the soil. Owing to their vital energy, the more energetic tribes shift their position and become diffused over vast countries where the geological and climatic conditions are exceedingly varied; but as they pass the boundaries of their native habitat, the types die away or become modified under the influence of the new surroundings. The harmony between the earth and its products is thus disturbed, but only to be gradually re-established, in conformity with the laws which govern all planetary phenomena. But in thus exercising their own peculiar energy so far as is consistent with the conditions of their life, the special faunas and floras only add to the wonderful harmony of the earth and of all that springs up and grows upon its surface.

Man, the "reasonable being," who so much delights in boasting of his free will, is nevertheless unable to render himself independent of the climates and physical conditions of the country which he inhabits Our liberty, in our relations with the land we live in, consists in recognizing its laws in order that we may live in accordance with them. However great may be the comparative facility of life and action which we have gained for ourselves by our intelligence and personal volition, we none the less remain mere products of the planet; fixed to its surface like imper-

ceptible animalculæ, we are carried along by all its movements, and are dependent on all its laws. Moreover, we do not belong to the earth merely as isolated individuals, for associations of men, taken as a whole, must at their origin have necessarily been moulded into shape on the earth on which they took their rise; in their inner organization they have been compelled to reflect the innumerable phenomena of the continental outline, their rivers and sea-coasts, and their circumjacent atmosphere. All the primitive facts of history are explained by the disposition of the geographical theatre on which they have taken place; we have even a right to assert that the history of the development of mankind has been written beforehand in sublime lettering on the plains, valleys, and coasts of our continents.

A geometrical parallelism is not, however, the point in question here. The resemblance between facts and the scenes that surround them is not an absolute one, as would be the image of an object reflected in a looking-glass. No; the accordance which exists between the globe and its inhabitants is composed both of analogies and contrasts: like all the harmonies to be perceived in organized bodies, it proceeds from conflict as much as from concord, and never ceases to oscillate round a shifting centre of gravity. The forces at work both on the surface and in the heart of the earth are always in action, and geological phenomena bear witness to this fact; in the same way, man is incessantly engaged in a conflict with the globe on which he dwells; having submitted to be a child of nature during the ages of primitive barbarism, he has gradually emancipated himself, and while endeavouring to adapt to his use the forces of the earth, he has, so to speak, made them his own. The action of the planet on man and the reaction of man on the planet are the agencies which have given rise to that harmony which forms the history of the human race. These facts, however, have become little more than truisms since the Humboldts, the Ritters, and the Guyots have by their labours established the solidarity which exists between man and the earth. When the illustrious author of the *Erdkunde* compiled, by his unassisted efforts, his great encyclopædia, the grandest geographic monument of the age, the leading idea which inspired him was that the earth is the body of mankind, and man is the soul of the earth. Without thus proudly appropriating to ourselves the globe on which we tread, we are still justified in asserting that though for a long time we were nothing more than its unconscious products, we have become increasingly active agents in its history.

It is now proved that man has existed on the earth since a very remote period. Written documents do not carry us back farther than thirty or forty centuries; the most ancient remains of edifices built at any previous epoch, which also may be called archives of stone, date back perhaps two thousand years further; but far beyond this short historic period, which scarcely comprises the lapse of one hundred and fifty generations, extends a space of time, certainly much longer, known to us only by pure tradition. Then mankind, rising to a more enlarged self-consciousness, linked age to age by legends, poems, and symbolic formula; the reminiscences of great events, migrations, wars of races, alliances, exterminations, and triumphs of industry, were incorporated into religion itself, and, in an increasingly varied form, were handed down from age to age as the heritage of nations. In still more ancient times, in the dim mist of bygone ages, our ancestors lived the life of wild beasts in forests and caves. Tradition, no less than history, is dumb as to this epoch of the human race; but the strata of the earth, explored in our time by geologists, are beginning to reveal to us both the existence and the customs of these ancestors of ours long unknown to us

To say nothing of the objects discovered at various epochs, at a time when science, still timid, refused to recognize the antiquity of man, so many human remains, and so many productions of primitive industry have been lately met with, that, comparatively speaking, there can no longer be any doubt as to the long duration of our species. Not only did our ancestors inhabit forests contemporaneously with the *Bos urus*, now banished into the Caucasus, and in Europe represented in a few parks by one or two specimens; but anterior to this epoch they also existed during the Glacial period, at a time when France and Germany presented the aspect now offered by Scandinavia, and the reindeer, now banished to the vicinity of the northern zone, frequented the glaciers of the Alps and the Pyrenees. At a still more ancient period, at an epoch when the European climate, which must subsequently have become so much cooler, was on the contrary much warmer than in the present time, the cave-men had for their contemporaries certain species of rhinoceros and elephants which are now extinct; and even then artists, humble predecessors of Phidias and Raphael, endeavoured to carve representations of mammoths upon their implements, which have been preserved in the earth of caves. Before this epoch man still existed, striving for mastery against a formidable enemy, the great cave-bear, representations of which he likewise left engraved on stone; and still further back, in the dim mist of ages, we learn from other remains, those of the *Elephas antiquus* and *meridionalis*, that our ancestors were already in being during a period whose life was once believed to have been separated from the present era by a succession of sudden cataclysms. How many thousands or even millions of years have elapsed since that time? This question as yet no one can answer.

The shape of the skull shows that the human remains found at Eyzies, near the border of Dordogne, must have belonged to a race which even now might be reckoned among the most beautiful of its kind; the skulls found by M. Garrigou in the caves of Ariége, and perhaps belonging to people of the historic epoch, are of very noble proportions; but the skulls found at Engis in Belgium, Neanderthal in Rhenish Prussia, Borreby in Denmark, and Eguisheim in Alsace, prove that numbers of the primitive inhabitants of western Europe were very much inferior to the civilized people of our days. Though perhaps more agile in pursuing their prey and more powerful in bringing it to the ground, these representatives of extinct races were less intelligent and had less of the man about them than we, and their facial angle bore some approach to that of the wild beasts with which they were compelled to struggle for very existence. As Professor Huxley remarks, the difference in capacity between the skull of civilized man and that of the man of Neanderthal or Borreby, much exceeds the difference which exists between ancient human skulls and those of the largest-sized monkeys. Must we therefore conclude, with Carl Vogt and many other anthropologists, that man is descended from one or several species of these quadrumana, which have gradually developed by the process of selection or through a contest for life extending throughout a long lapse of ages? We have here a theory which, far from being humiliating to mankind, should on the contrary be a source of pride; our own immense progress would justify a very considerable expectation on this point. Nevertheless, although it is all very well to set up and discuss these grave hypotheses, we must, however, be on our guard against accepting them as demonstrated facts as long as no direct evidence has been definitely brought forward.

Since we are necessarily still in doubt as to the very origin of mankind, it is obviously impossible to ascertain whether the different races of the earth are

descended from one couple or from several primitive groups. Is it a fact that all men, black and white, red and copper-coloured, own the same Adam as their progenitor, and the same Eve as their common mother? Or has each continent each isolated tract of land, produced autochthonous races distinct from every other, as it had previously produced its peculiar flora and fauna? Although this question is as yet insoluble, none is more discussed by anthropologists. Some maintain that the primitive unity of the race is an indisputable fact, and that it could not be denied without making a kind of attack against the majesty of mankind; others are of opinion that there were three, four, five, ten, or eleven primitive groups; there are some also who talk of hundreds of various races which have sprung up here and there at different epochs on continents and islands, like the plants, the seeds of which were sown, so to speak, at random. In support of this theory they cite the well-known fact that the types of fossil man in western Europe present contrasts much more striking than those observed in the races of our time.

Moreover, the passions of our nature, having no alliance with science, have been mixed up in this debate. At the time when the American Republic was still unfortunate enough to reckon along with its thirty millions of white men, the freest in the universe, four millions of negroes condemned to the most degrading slavery, both polygenists and monogenists used to dispute *à outrance* in scientific language; they went so far as to invent arguments, not to establish the truth, but either to justify or to curse slavery. Even among those who believed in the tradition of the primitive unity of the human race, many asserted, out of hatred to the blacks, that this unity has been broken during the course of ages, and that the children of slavery were for ever doomed to the lash and to the iron collar. These contests, provoked by the strife of interest and feelings, have not resulted in any scientific certainty, and the origin of our race remains as obscure as ever. This ignorance is naïvely illustrated by most of the myths, which recount how the life of the first men began by sleep. "Nothing was in being," say the old men of an Indian tribe, "all was null and void; there was no sky, no earth, no sea, no shore. Suddenly seven warriors found themselves seated on the edge of a lake smoking the calumet of peace, and their wives were already working in the wigwams." No legend brings more vividly before us that man passed his infancy as if in a dream; his first commencement was living without knowing it.

It matters moreover but little whether man is descended from one or several primitive couples of ancestors; it is of little importance whether races so diverse in their nature were all begotten by the same family, or whether they were born in different countries and at different epochs, provided that this unity, though doubtful in the past, becomes a matter of certainty in the future. This is one of those great questions which anthropologists are now putting to themselves, and we believe that it will be very near its solution when the results shown by experience are adhered to in good faith. According to some savants, various races cannot blend one with the other: the black cannot permanently unite with the white man; the Redskin, the South Sea islander, the Arab, and even the Chinese, can never enter the great family of their brother nations; and more than this, the Hindu, although no less Aryan in his origin than the western European, and actually his precursor in arts and sciences, is compelled to remain excluded from the circle of the proud Celtic and Germanic races without renewing the former bonds of parentage. According to this theory, which is absolutely enunciated by some and more or less softened down by others, the progeny of any union between different races would be a family of hybrids destined either to die away from

sterility, or to produce successive generations the special type of which, growing weaker and weaker, could only ultimately result in the reproduction of one of the two original races. And even a more melancholy fact! Certain inferior tribes, altogether incapable of uniting with the masters of the earth or even of living in the same civilised state, will have no alternative left but to die out, the earth not being large enough for them and for the men of the victorious race.

Alas! the self-styled civilised man has often proved his superiority over other races by a merciless course of destruction; he has hunted them down like game, sometimes in order to seize their land, their jewels, or their arms, sometimes to make slaves of them, and sometimes merely for tasting the pleasures of wholesale slaughter. The number of victims which have been thus sacrificed during the last four centuries must be computed by millions and millions, and whole tribes, and even nations, have completely disappeared. It may be easily understood that in the face of this immense massacre the fusion of races could not be effected. Nevertheless, if the greater part of Europeans, instead of showing themselves to be mere exterminators and clearing away all before them, had been somewhat less of barbarians; if they had adhered to the plan of evincing their native generosity by coming forward as friends and as benevolent and just individuals, can we believe that they would have failed in coming to a good understanding with the natives, and that an union would not have been easy between the distinct races? In every part of the world, the common understanding of what is just and right would have marvellously facilitated the alliance. If it is a fact that fusions between different races can produce nothing more than sterile hybrids, the case is plain—mankind is condemned to death, and to a rapid death; for peoples and races are every day more and more mixed up, the frontiers of countries are disappearing, and by cross-breeding upon cross-breeding all men will ultimately become one and the same family.

In spite of the terrible conflicts which have taken place, in spite of exterminations, and in spite of slavery, the whole of South America, the republics of Central America, the West Indies, and a portion of the United States, are now peopled with a mixed race, in which blacks, whites, and redskins are found blended together. Is not that part of the earth which we call the New World inhabited by newly formed peoples, the type of which is in no way confused with that of either of the races which produced it, but is all its own? Is it not a fact that all these populations, which resemble the European in intelligence and ideas, the Indian in an indomitable spirit of stubbornness, and the African in his enthusiasm and gentle qualities, are living proofs that the various human races might easily be united into one in spite of the difference in their origin? Subjected to the influences of rapid changes, journeys without end, the various elements brought in by emigration, the intermixtures between families, the modification of climates produced by cultivation, the types of mankind, becoming more and more mobile, blend and ultimately unite: if these types in former days remained unchanged, the cause was the immobility of nations. The Egyptian of our time, although characterized by slight modifications pointed out by Brugsch, is much the same as the figures which we see enslaved and bent down on the fronts of obelisks and on the pedestals of statues. But there is no painting, there is no design engraved either on stone or metal, which has ever given us any indication of the type of the modern North American or *Yankee*, or of the Spanish-American.

In his anniversary address to the Anthropological Institute, Professor W. H. Flower proposes a comprehensive classification of all the races of mankind based

on the assumption of their primordial unity, or descent from a single stock. This eminent anthropologist observes that, after an independent study of the subject extending over many years, he has come to the conclusion that primitive man has in the course of ages diverged into three extreme types, represented by the Caucasian of Europe, the Mongolian of Asia, and the Ethiopian of Africa, and that all existing individuals of the species can be ranged around these types, or somewhere or other between them. Large numbers are doubtless the descendants of direct crosses in varying proportions between well-established extreme forms; for, notwithstanding opposite views formerly held by some authors on this subject, there is now abundant evidence of the wholesale production of new races in this way. Others may be the descendants of the primitive stock, before the strongly marked existing distinctions had taken place, and therefore present, though from a different cause from the last, equally generalised characters. In these cases it can only be by most carefully examining and balancing all characters however minute, and finding out in what direction the preponderance lies, that a place can be assigned to them. It cannot be too often insisted on, that the various groups of mankind, owing to their probable unity of origin, the great variability of individuals, and the possibility of all degrees of intermixture of races at remote or recent periods of the history of the species, have so much in common that it is extremely difficult to find distinctive characters capable of strict definition, by which they may be differentiated. It is more by the preponderance of certain characters in a large number of members of a group, than by the exclusive or even constant possession of these characters in each of its members, that the group as a whole must be characterised.

"To begin with the Ethiopian, Negroid, or Melanian, or 'black' type. It is characterised by a dark, often nearly black, complexion; black hair, of the kind called 'frizzly' or, incorrectly, 'woolly,' *i.e.* each hair being closely rolled up upon itself, a condition always associated with a more or less flattened or elliptical transverse section; a moderate or scanty development of beard; an almost invariably dolichocephalic skull; small and moderately retreating malar bones (mesopic face); a very broad and flat nose, platyrhine in the skeleton; moderate or low orbits; prominent eyes; thick, everted lips; prognathous jaws; a long forearm.

"The most characteristic examples of the second great type, the Mongolian or Xanthous or 'yellow,' have a yellow or brownish complexion; coarse, straight hair, without any tendency to curl, and nearly round in section, on all other parts of the surface except the scalp, scanty and late in appearing; a skull of variable form, mostly mesocephalic (though extremes both of dolichocephaly and brachycephaly are found in certain groups of this type); a broad and flat face, with prominent, anteriorly projecting malar bones (platyopic face); nose small, mesorhine or leptorhine; orbits high and round, with very little development of glabellaor supraciliary ridges; eyes sunken, and with the aperture between the lids narrow; in the most typical members of the group with a vertical fold of skin over the inner canthus, and with the outer angle slightly elevated; jaws mesognathous.

"The last type, which, for want of a better name, I still call by that which has the priority, Caucasian, or 'white,' has usually a light-complexioned skin (although in some, in so far aberrant cases, it is as dark as in the Negroes); hair fair or black, soft, straight, or wavy, in section intermediate between the flattened and cylindrical form; beard fully developed; form of cranium various, mostly mesocephalic; malar bones retreating; face narrow and projecting in the middle

line (pro-opic); orbits moderate; nose narrow and prominent (leptorhine); jaws orthognathous.

"In endeavouring further to divide up into minor groups the numerous and variously modified individuals which cluster around one or other of these great types, a process quite necessary for many practical or descriptive purposes, the distinctions afforded by the study of physical characters are often so slight that it becomes necessary to take other considerations into account, among which geographical distribution and language hold an important place.

"I.—The Ethiopian or Negroid races may be primarily divided as follows:—

"A. African or typical Negroes—inhabitants of all the central portion of the African continent, from the Atlantic on the west to the Indian Ocean on the east, greatly mixed all along their northern frontier with Hamitic and Semitic Melanochroi, a mixture which, taking place in various proportions and under varied conditions, has given rise to many of the numerous races and tribes inhabiting the Soudan.

"A branch of the African Negroes are the Bantu—distinguished chiefly, if not entirely, by the structure of their language. Physically indistinguishable from the other Negroes where they come in contact in the equatorial regions of Africa, the Southern Bantu, or Kaffirs, as they are generally called, show a marked modification of type, being lighter in colour, having a larger cranial capacity, less marked prognathism, and smaller teeth. Some of these changes may possibly be due to crossing into the next race.

"B. The Hottentots and Bushmen form a very distinct modification of the Negro race. They formerly inhabited a much larger district than at present; but, encroached upon by the Bantu from the north and the Dutch and English from the south, they are now greatly diminished, and indeed threatened with extinction. The Hottentots especially are much mixed with other races, and under the influence of a civilisation which has done little to improve their moral condition, they have lost most of their distinctive peculiarities. When pure bred they are of moderate stature, have a yellowish-brown complexion, with very frizzly hair, which, being less abundant than that of the ordinary Negro, has the appearance of growing in separate tufts. The forehead and chin are narrow, and the cheek-bones wide, giving a lozenge shape to the whole face. The nose is very flat, and the lips prominent. In their anatomical peculiarities, and almost everything except size, the Bushmen agree with the Hottentots; they have, however, some special characters, for while they are the most platyrhine of races, the prognathism so characteristic of the Negro type is nearly absent. This, however, may be the retention of an infantile character so often found in races of diminutive stature, as it is in all the smaller species of a natural group of animals. The cranium of a Bushman, taken altogether, is one of the best marked of any race, and could not be mistaken for that of any other. Their relation to the Hottentots, however, appears to be that of a stunted and outcast branch, living the lives of the most degraded of savages among the rocky caves and mountains of the land of which the comparatively civilised and pastoral Hottentots inhabited the plains.

"Perhaps the Negrillos of Hamy, certain diminutive round-headed people of Central and Western equatorial Africa, may represent a distinct branch of the Negro race, but their numbers are few, and they are very much mixed with the true Negroes in the districts in which they are found. They form the only exceptions to the general dolichocephaly of the African branch of the Negro race.

"C. *Oceanic Negroes* or *Melanesians*.—These include the Papuans of New Guinea

and the majority of the inhabitants of the islands of the Western Pacific, and form also a substratum of the population, greatly mixed with other races, of regions extending far beyond the present centre of their area of distribution.

"They are represented, in what may be called a hypertypical form, by the extremely dolichocephalic Kai Colos, or mountaineers of the interior of the Fiji Islands, although the coast population of the same group have lost their distinctive characters by crossing. In many parts of New Guinea and the great chain of islands extending eastwards and southwards ending with New Caledonia, they are found in a more or less pure condition, especially in the interior and more inaccessible portions of the islands, almost each of which shows special modifications of the type recognisable in details of structure. Taken altogether their chief physical distinction from the African Negroes lies in the fact that the glabella and supra-orbital ridges are generally well developed in the males, whereas in Africans this region is usually smooth and flat. The nose, also, especially in the northern part of their geographical range, New Guinea, and the neighbouring islands, is narrower (often mosorhine) and prominent. The cranium is generally higher and narrower. It is, however, possible to find African and Melanesian skulls quite alike in essential characters.

"The now extinct inhabitants of Tasmania are probably pure, but aberrant, members of the Melanesian group, which have undergone a modification from the original type, not by mixture with other races, but in consequence of long isolation, during which special characters have gradually developed. Lying completely out of the track of all civilisation and commerce, even of the most primitive kind, they were little liable to be subject to the influence of any other race, and there is in fact nothing among their characters which could be accounted for in this way, as they are intensely, even exaggeratedly, Negroid in the form of nose, projection of mouth, and size of teeth, typically so in character of hair, and aberrant chiefly in width of skull in the parietal region. A cross with any of the Polynesian or Malay races sufficiently strong to produce this would, in all probability, have also left some traces on other parts of their organisation.

"The inhabitants of the continent of Australia have long been a puzzle to ethnologists. Of Negroid complexion, features, and skeletal characters, yet without the characteristic frizzly hair, their position has been one of great difficulty to determine. They have, in fact, been a stumbling-block in the way of every system proposed. The solution, supported by many considerations too lengthy to enter into here, appears to lie in the supposition that they are not a distinct race at all, that is, not a homogeneous group formed by the gradual modification of one of the primitive stocks, but rather a cross between two already formed branches of these stocks. According to this view, Australia was originally peopled with frizzly-haired Melanesians, such as those which still do, or did till the recent European invasion, dwell in the smaller islands which surround the north, east, and southern portions of the continent, but that a strong infusion of some other race, probably a low form of Caucasian Melanochroi, such as that which still inhabits the interior of the southern parts of India, has spread throughout the land from the north-west, and produced a modification of the physical characters, especially of the hair. This character of hair must be a specialisation, for it seems very unlikely that it was the attribute of the common ancestors of the human race.

"D. The fourth branch of the Negroid race consists of the diminutive round-headed people called Negritos, still found in a pure or unmixed state in the Andaman Islands, and forming a substratum of the population, though now greatly

mixed with invading races, especially Malays, in the Philippines, and many of the Islands of the Indo-Malayan Archipelago, and perhaps of some parts of the southern portion of the mainland of Asia. They also probably contribute to the varied population of the great island of Papua or New Guinea, where they appear to merge into the taller, longer-headed, longer-nosed Melanesians proper. They show, in a very marked manner, some of the most striking anatomical peculiarities of the Negro race, the frizzly hair, the proportions of the limbs, especially the humero-radial index, and the form of the pelvis; but they differ in many cranial and facial characters, both from the African Negroes on the one hand, and the typical Oceanic Negroes, or Melanesians, on the other, and form a very distinct and well-characterised group.

"II.—The principal groups that can be arranged around the Mongolian type are—

"A. The Eskimo, who appear to be a branch of the typical North Asiatic Mongols, who in their wanderings northwards and eastwards across the American continent, isolated almost as perfectly as an island population would be, hemmed in on one side by the eternal Polar ice and on the other by hostile tribes of American Indians, with which they rarely, if ever, mingled, have gradually developed characters most of which are strongly expressed modifications of those seen in their allies who still remain on the western side of Behring's Straits. Every special characteristic which distinguishes a Japanese from the average of mankind is seen in the Eskimo in an exaggerated degree, so that there can be no doubt about their being derived from the same stock. It has also been shown that these special characteristics gradually increase from west to east, and are seen in their greatest perfection in the inhabitants of Greenland; at all events, in those where no crossing with the Danes has taken place. Such scanty remains as have yet been discovered of the early inhabitants of Europe present no structural affinities to the Eskimo, although it is not unlikely that similar external conditions may have led them to adopt similar modes of life. In fact, the Eskimo are such an intensely specialized race, perhaps the most specialized of any in existence, that it is probable that they are of comparatively late origin, and were not as a race contemporaries with the men whose rude flint tools found in our drifts excite so much interest and speculation as to the makers, who have been sometimes, though with little evidence to justify such an assumption, reputed to be the ancestors of the present inhabitants of the northernmost parts of America.

"B. The typical Mongolian races constitute the present population of Northern and Central Asia. They are not very distinctly, but still conveniently for descriptive purposes, divided into two groups, the Northern and the Southern.

"*a.* The former, or Mongolo-Altaic group, are united by the affinities of their language. These people, from the cradle of their race in the great central plateau of Asia, have at various times poured out their hordes upon the lands lying to the west, and have penetrated almost to the heart of Europe. The Finns, the Magyars, and the Turks, are each the descendants of one of these waves of incursion, but they have for so many generations intermingled with the peoples through whom they have passed in their migrations, or have found in the countries in which they have ultimately settled, that their original physical characters have been completely modified. Even the Lapps, that diminutive tribe of nomads inhabiting the most northern parts of Europe, supposed to be of Mongolian descent, show so little of the special attributes of that branch that it is difficult to assign them a place in it in a classification based upon physical characters. The Japanese are said by their

language to be allied rather to the Northern than to the following branch of the Mongolian stock.

"*b*. The Southern Mongolian group, divided from the former chiefly by language and habits of life, includes the greater part of the population of China, Thibet, Burmah, and Siam.

"C. The next great division of Mongoloid people is the Malay; subtypical, it is true, but to which an easy transition can be traced from the most characteristic members of the type.

"D. The brown Polynesians, Malayo-Polynesians, Mahoris, Sawaioris, or Kanakas, as they have been variously called, seen in their greatest purity in the Samoan, Tongan, and Eastern Polynesian Islands, are still more modified, and possess less of the characteristic Mongolian features; but still it is difficult to place them anywhere else in the system. The large infusion of the Melanesian element throughout the Pacific must never be forgotten in accounting for the characters of the people now inhabiting the islands, an element in many respects so diametrically opposite to the Mongolian, that it would materially alter the characters, especially of the hair and beard, which has been with many authors a stumbling-block to the affiliation of the Polynesian with the Mongol stock. The mixture is physically a fine one, and in some proportions produces a combination, as seen, for instance, in the Maories of New Zealand, which in all definable characters approaches quite as near, or nearer, to the Caucasian type, than to either of the stocks from which it may be presumably derived. This resemblance has led some writers to infer a real extension of the Caucasian element at some very early period with the Pacific Islands, and to look upon their inhabitants as the product of a mingling of all three great types of men.

"E. The native population (before the changes wrought by the European conquest) of the great continent of America, excluding the Eskimo, present, considering the vast extent of the country they inhabit and the great differences of climate and other surrounding conditions, a remarkable similarity of essential characters, with much diversity of detail.

"The construction of the numerous American languages, of which as many as twelve hundred have been distinguished, is said to point to unity of origin, as, though widely different in many respects, they are all, or nearly all, constructed on the same general grammatical principle—that called *polysynthesis*—which differs from that of the languages of any of the Old World nations. The mental characteristics of all the American tribes have much that is in common; and the very different stages of culture to which they had attained at the time of the conquest, as that of the Incas and Aztecs, and the hunting or fishing tribes of the north and south, which have been quoted as evidence of diversities of race, were not greater than those between different nations of Europe, as Gauls and Germans on the one hand, and Greeks and Romans on the other, in the time of Julius Cæsar. Yet all these were Aryans, and in treating the Americans as one race it is not intended that they are more closely allied than the different Aryan peoples of Europe and Asia. The best argument that can be used for the unity of the American race—using the word in a broad sense—is the great difficulty of forming any natural divisions founded on physical characters. The important character of the hair does not differ throughout the whole continent. It is always straight and lank, long and abundant on the scalp, but sparse elsewhere. The colour of the skin is practically uniform, notwithstanding the enormous differences of climate under which many members of the group exist. In the features and cranium certain special modifications prevail in

different districts, but the same forms appear at widely-separated parts of the continent.

"Now that the high antiquity of man in America, perhaps as high as that he has in Europe, has been discovered, the puzzling problem, from which part of the Old World the people of America have sprung, has lost its significance. It is quite as likely that the people of Asia may have been derived from America as the reverse. However this may be, the population of America had been, before the time of Columbus, practically isolated from the rest of the world, except at the extreme north. Such visits as those of the early Norsemen to the coasts of Greenland, Labrador, and Nova Scotia, or the possible accidental stranding of a canoe containing survivors of a voyage across the Pacific or the Atlantic, can have had no appreciable effect upon the characteristics of the people. It is difficult, therefore, to look upon the anomalous and special characters of the American people as the effects of crossing, as was suggested in the case of the Australians, a consideration which gives more weight to the view of treating them as a distinct primary division.

"III. The Caucasian, or white division, according to my view, includes the two groups called by Professor Huxley Xanthochroi and Melanochroi, which, though differing in colour of eyes and hair, agree so closely in all other anatomical characters, as far, at all events, as has at present been demonstrated, that it seems preferable to consider them as modifications of one great type than as primary divisions of the species.

"Whatever their origin, they are now intimately blended, though in different proportions, throughout the whole of the region of the earth they inhabit; and it is to the rapid extension of both branches of this race that the great changes now taking place in the ethnology of the world is mainly due.

"A. The Xanthochroi, or blonde type, with fair hair, eyes, and complexion, chiefly inhabit Northern Europe—Scandinavia, Scotland, and North Germany—but, much mixed with the next group, they extend as far as Northern Africa and Afghanistan. Their mixture with Mongoloid people in North Europe has given rise to the Lapps and Finns.

"B. Melanochroi, with black hair and eyes, and skin of almost all shades from white to black. They comprise the great majority of the inhabitants of Southern Europe, Northern Africa, and South-west Asia, and consist mainly of the Aryan, Semitic, and Hamitic families. The Dravidians of India, and probably the Ainos of Japan, the Maoutze of China, also belong to this race, which may have contributed something to the mixed character of some tribes of Indo-China and the Polynesian Islands, and, as before said, given at least the characters of the hair to the otherwise Negroid inhabitants of Australia. In Southern India, they are probably mixed with a Negrito element, and in Africa, where their habitat becomes conterminous with that of the Negroes, numerous cross races have sprung up between them all along the frontier line. The ancient Egyptians were nearly pure Melanochroi, though often showing in their features traces of their frequent intermarriage with their Ethiopian neighbours to the south. The Copts and fellahs of modern Egypt are their little-changed descendants."

CHAPTER LXV.

INFLUENCE OF CLIMATE.—TROPICAL ZONE.—FRIGID ZONE.—TEMPERATE ZONE.

ENUMERATING, in his *History of Civilization in England*, the various natural agencies that must have exercised the most potent influence in modifying one way or the other the human race in its infancy, Buckle gives the first place to climate, and then mentions, in the order of their importance, food, the soil, and the general aspect of the land. At the same time this arrangement can have but a relative value, and requires to be modified according to the varying conditions of different countries. Thus for the Puelche and the Pehuenche of the Patagonian plains, as well as for the Gaucho of the Argentine pampas, an exclusively animal diet appears to impart more vigour than the other elements of the environment.

The long and severe winters of Lapland exercise the most decided influence on its dwarfish inhabitants; the habit of life, character, and usages of races living in the wilderness or in a watery domain, are mainly determined by the desert sands or the "melancholy ocean."

Even the original features of a people become modified under the action of the land, not only after the lapse of many generations, but even in a few years on the individual himself. How many peasant women readily assume the outward appearance of high-born dames! How many rude provincials have been quickly transformed to elegant and fashionable Parisians!

The colony adapts itself to the customs of its new home, and the mariner wrecked among savage tribes rapidly acquires the speech, the sentiments, the very thoughts of the people who have given him a friendly welcome. On his return from Turkestan the "false dervish," Arminius Vambery, introduced into Hungary the seeds of the exquisite melons of Khiva, and went about accompanied by an Uzbek Tartar. In four years the imported melons had lost all their flavour, and the Uzbek had become a Magyar in outward appearance.

The various conditions and surroundings regulating climate are so extremely diverse in different parts of the world, it is only possible in the most general way to point out their influence on the inhabitants. Thus in the tropical zone there is a complete contrast between deserts destitute of water and verdure, and the luxuriant lands on which at one time the sun shoots forth its flame-like rays, and at another the clouds pour down their showers in cataracts.

The development of life is rapid in climates where the winter season follows immediately upon tropical heat; it advances with rapid strides, and death also

hastens on behind it. Gigantic trees inhale currents of carbonic acid through their thirsty leaves, and absorb them into their numerous tissues; bamboos may almost be seen to grow, and marshes are concealed under isles of floating herbage. No sooner does a storm overthrow the mighty giants of the forest than fresh vegetation springs forth from the shattered bark. Thus life, ever indefatigable, causes multitudes of new organisms to shoot out from the death of the old. In this fruitful climate, where the air is pervaded with heat and saturated with moisture, those vegetables which are used for the food of man grow in the greatest abundance. In many regions of the tropical zone all that man has to do when in search of food is to shake the branches of the trees or pull up roots from the ground. His needs are so very few and life is so easy to him, that he cares little about it; he is not compelled to sustain it by dint of work, but it meets him as it were half way, and he almost despises it, because its favours are so generously offered. He therefore meets death without a regret, and not one tear is shed when he closes his eyes for ever. Sudden epidemics visit the inhabitants, as storm-clouds beat upon a forest; sometimes even famine carries away whole populations, who have not been wise enough to store up the resources offered to them by nature against future times of want. But what matters the death of a man or even that of whole tribes? Children innumerable take the place of those who have departed, and grow up like the grass in a newly mown meadow. Thus the mildness of the climate, the fertility of the soil, the exuberance of life, and the suddenness of death, take an equal part in maintaining man in his native carelessness and idleness. Taken as a religious being, all he can do is to bend in silence before the majesty of mighty nature. Her violence is too terrible, her energies are too impetuous, the great alternations of her actions are too regular, for the feeble being placed in her midst to be anything but a slave. He will worship her in all her phenomena: in the rays of the sun, because they burn and destroy; in the clouds, because they peal forth thunders; in the dark forest, because serpents and tigers are hidden in its depth; in all that surround him, because everything lives with an irresistible force of life which may at any time cause his death. The stupendous work which is unceasingly going on around him hinders any personal labour; he thinks but little; when, like the Hindu, he meditates and contemplates the laws of nature, his ideas somewhat tend to the profound and the immutable, like the laws of which they are the reflection.

The rich nature of the tropics even on account of that richness is, as we see, not the most favourable to the progress of mankind, but the frigid zone is still less fitted to be the residence of prosperous nations. But a few tribes have wandered into the solitudes of these countries, where they have struggled painfully with the climate in order to extort from it each day enough to keep up a miserable existence. As, on account of glaciers and the absence of vegetation, they cannot penetrate far into the interior of the islands and continents on which they live, they build their wood or snow huts on the sea-shore. There, at least, the wind now and then wafts to them a few gusts of equatorial air, there the counter-currents drive upon the shore water which has come from the tropics, and still retains something of its primitive warmth; and when the sea is not too stormy, or too much covered with drifting icebergs, the fisherman is able to venture out in his leathern boat in quest of seals and fish. When he has pierced with his harpoon the animals which are to serve as food for his family, he returns to the small black hole which forms his miserable retreat, where, warming himself by the flame of a lamp, he spends the long winter night, which seems as if it would never end, for even

the sun, the source of heat for all terrestrial life, abandons the frigid zone for whole weeks and months, while the aurora, which at intervals takes its place, sheds but a livid gleam, a mere phantom of the day. Existence is a difficult matter during this long and gloomy winter; famine, too, often makes great havoc among these people, and sometimes whole tribes have disappeared without leaving a trace behind them. How could it be otherwise than that the mind of the Greenlander, the Esquimaux, and the Kamtchadale should suffer under the influence of the desolate climate of the polar regions? All travellers relate that the most simple pleasures are sufficient to fill up the cup of joy for artless beings like these, whose life is always so monotonous; in their struggle for existence ambition does not form a part, for the main point with them is to procure food, and the soil is too ill adapted for cultivation, and the climate is too inclement, for them to be able to counteract the difficulties presented by the land, and to make any endeavour to appropriate it for their own use. They are loving in disposition, for a family living together as they do in their snow huts must be all the world to each other; they are attached to their native land and die when obliged to leave it, because their ideas are as unsophisticated as the country in which they were born, and there only can they experience the simple pleasures and peaceful joys which refresh them after their labours. Even among nations there are some that are always children, and they perish when they are torn away from their mother's breast.

The two temperate zones, and particularly that in the Northern hemisphere, are the portions of the planetary surface which have been the most favoured in the development of the human race; and when the more or less civilized nations of Western Europe and North America proudly attribute to their inherent virtues the great progress attained by them, they little know how much is owing to the favourable climate which has assisted their efforts.

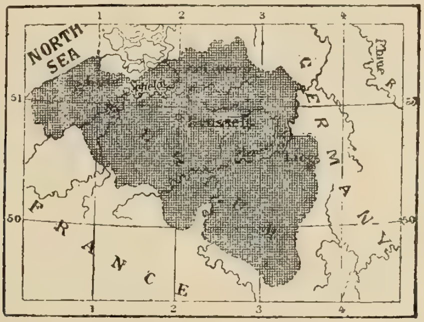
The distinctive characteristic of the temperate zone is the equal and periodical alternation of the hot and cold seasons. In the tropics, the mean temperature varies but slightly, and in the frigid zone, intense cold yields to a milder climate for only a few weeks during a very short summer; but in the tract of land included between the two extreme zones, heat and cold follow each other regularly, so as to form two well-defined seasons following the path of the sun on the ecliptic. The nations of the temperate zones are reared in a powerful climatic tide, the flow of which rises from the equator towards the poles during spring and summer, the ebb descending from the poles towards the equator during the autumn and winter. The extremes of temperature are always separated by long intervals of weeks and months, and the influence of contrary climates is only shown by successive gradations. In the temperate zone nature wears alternately a joyful and a melancholy aspect; during the warm season the earth is gay with smiles, covered with flowers and foliage, it fills the air with its perfume, and abundantly absorbs the rays of heat, light, and life which the sun sends down to it; in winter time nearly all that is green seems to have faded, the delicate outlines of the bare branches on the trees stand out in relief against the sky, and the ground is often covered with snow as if to shield it from the outer air, and in silence and retirement to prepare for the germs of life which will bud forth in the spring.

This succession of seasons does not, however, take place so abruptly as to bring about any injury to the organism of man. Months, weeks, and days follow their course in the circle of the year with a harmonious and measured step, and man, borne along by the seasons, must involuntarily be carried along by their movement.

During the course of a year he passes through climates of the most various nature, and, gazing on a landscape which is ever changing, he alternately sees nature like that in the tropics and that in the poles fluctuating around him. The scenes which follow one another season after season represent both to his body and mind journeys of many hundreds of miles; he is, so to speak, constantly changing his habitat on the surface of the globe. Nature is exhibited to him in all the beauty she wears in every climate, rarely presenting to him the fearful aspects she presents in the zones of hurricanes and boundless snows.

The variety of climatic phenomena, and the quiet way in which they follow one another, have made the temperate zone the best climate for the human race. The life of man is developed better than anywhere else in these regions, where the action of nature is produced energetically and regularly, and the forces proceeding from the equator and those proceeding from the poles mingle with each other, increasing by their combination the number of their phenomena, and yet, at the same time, mutually diminishing the violence of their action. In consequence of the regular oscillation of their zone of contact, these forces also bring about a condition of constant movement and equilibrium; man, to whom they have given the breath of life, may, by contemplating their alternations, perceive the immutable

Fig. 186.—Density of the Population in Belgium



eternity of the laws which guide them, and the ever-varying appearance of the facts which spring from them. A still more important fact is that man is constantly incited to labour, for notwithstanding the beneficence of nature in these temperate regions, it is only shown in moderation, and to those who study and understand her. In the spring, the ground must be cultivated in prospect of winter, and each season must be made a preparation for that which follows. Confident in the bounty of the earth, the labourer learns to deprive himself of a part of the grain which forms his very existence, knowing that some day he will gather a harvest from it; by incessant and successful efforts he acquires shrewdness, knowledge, cheerfulness, and love of life.

Therefore, in all the countries of the temperate zone which are blessed with a fertile, well-watered, healthy soil, and are provided with easy channels of communication, there has always been a numerous and increasing population, in spite of the wars, massacres, and invasions to which rival ambition has so often given rise. As far as Asia is concerned, the central part of the temperate region is the locality where we find that "rich central flower" which by itself comprehends more than a quarter of the human race; at the other extremity of the Old World, it is also towards the middle of the same zone, in Belgium, England, and northern

France, that we find swarms of men living in the closest proximity to one another. Belgium is the country which has the largest population as compared to the whole world, and contains more than one inhabitant to each acre, or at least a quantity twenty times greater than the rest of the continent. Greece, which is one of the least populous countries of temperate Europe, is, however, in proportion three times more thickly populated than all the dry land of the earth taken as a whole; the comparative populations of the two countries may be imagined from the

Fig. 187.—Density of the Population in Greece.

two preceding maps, in which, according to a somewhat different system from that of M. Minard, the density of the inhabitants, for an equal surface, is made proportional to the number of squares. The space of 2050 miles in width comprehended between the 25th and 26th degrees north latitude, which is not even a third of the continental surface, contains two-thirds of the population of the globe, and this is the tract of country where, in our time, the number of inhabitants is still increasing with the greatest rapidity.

CHAPTER LXVI.

INFLUENCE OF THE RELIEF OF THE LAND ON MANKIND.—TABLELANDS, MOUNTAINS, HILLS, AND PLAINS.

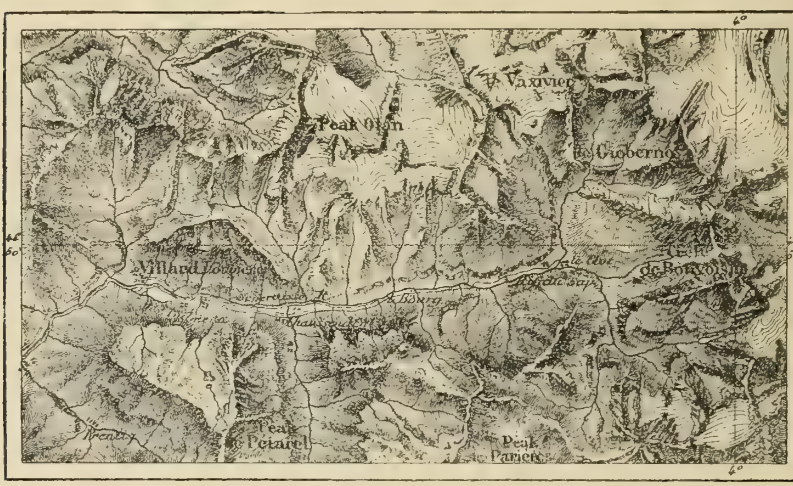
THROUGHOUT the globe the inequalities in level of the various continents have a singular influence upon climate, and consequently also modify in the most varied manner the destinies of nations. Instead of following one another regularly from the equator to the poles according to the lines of latitude, the zones of temperature intersect and rise one above another; the surrounding conditions here and there are abruptly varied, and with these conditions the populations also vary.

Taking the mighty fabric of continents, there are some table-lands which are of the greatest importance in the history of mankind. Rising up in the midst of plains, with a system of mountains, rivers, and lakes peculiar to themselves, with a flora and fauna belonging exclusively to them, and a particular climate, always colder, and generally much drier, than that of the lower lands, table-lands offer the most difficulty barrier to the migration of nations; for the wide seas, formerly quite impassable, are now easily crossed by ships, and nations of the same origin settle on opposite shores, and become more and more united by voyages and commerce. Table-lands in cold or even temperate regions are not merely boundaries between nations; numbers of them are, indeed, nothing but deserts on account of the dryness of the soil, the rigour of the weather, the violence of the winds, and the snow-storms. In South America, travellers can never venture without danger on the table-lands of the Andes between Chili and the Argentine Republic; even in France the almost uninhabited *causses* of Lévezon, Cavalerie, and Sévérac are very dangerous to cross in winter-time, and not unfrequently carriages are left there buried in the snow. Most of the table-lands of the torrid zone are equally desert, owing to the dryness of the air and the soil, and also on account of the thick saline beds with which the ground is covered; but by a remarkable contrast, there are also certain table-lands which, in the region of intense heat, are the most favourably situated countries for the progress of man. Like rich hanging gardens, rising to a height of 3000, 6000, or 8000 feet in the air, these table-lands bear on their marble or granite pillars a fragment as it were of the temperate zone, with its climate, its products, and its comparatively prosperous people. Thus, the table-land of Ethiopia, peopled by a race distinguished from all others in Africa for its intellect, dignity, bravery, attainments, and progress, rises like an enormous citadel between the deserts of the west, the marshy valleys of the north and south,

and the burning shores of the Red Sea. In the same way in America the great Peruvian table-land once inhabited by the Incas, the high lands of Granada, where the Muyscas and other Indian nations lived, and the table-lands of Guatemala, Yucatan, and Anahuac, are almost the only parts of the New World where original civilization has spontaneously developed itself: flowers which could not grow in any other soil, yet brutally torn up by the conquering Spaniard.

Thus it is according to the latitude, the rainfall, and the arrangement of the surrounding country, that table-lands have a favourable or unfavourable effect on the destinies of mankind; on the one hand, as in the whole of central Asia especially, there are thinly scattered and often nomadic populations, in quest of springs and streams of water and fertile meadows, and very frequently also engaged in expeditions of murder and pillage; on the other hand, as in tropical America, there are comparatively peaceable nations, busied in agriculture, manufactures, and commerce, and gradually developing their autochthonous civilisation. Mountains also exercise very different influences on the inhabitants of their valleys, according

Fig. 188 —Valgodemar.

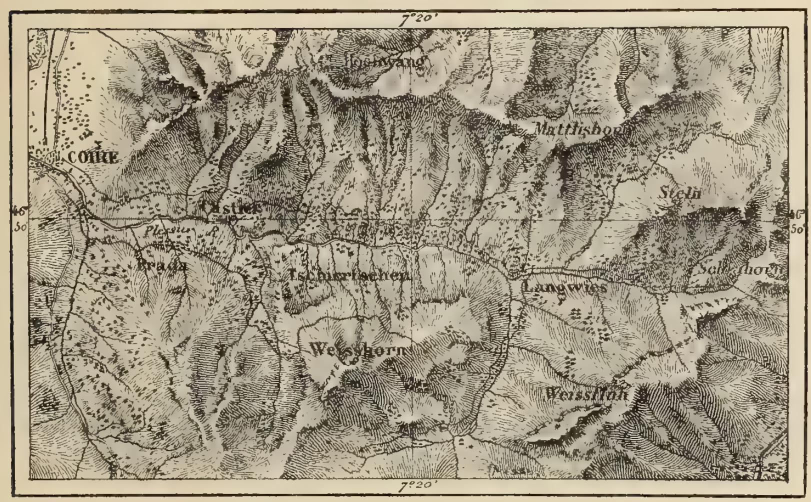


to the altitude of the lands inhabited, their temperature, and other climatic conditions, the nature of the rocks, the aspect of the slopes, and the abundance of light. How great, in this respect, is the contrast between the Italian valleys of the central Alps and the French valleys of the mountains of Dauphiné! The former are steeped in sunshine, bathed by the blue waters of the great lakes, and open widely on to the verdant plains of Lombardy; from the summit of the headlands, the villagers survey an immense horizon, exhibiting, as in a perfect picture, the most charming varieties both of land and cultivation. On the contrary, in the dreary district of Valgodemar, in the gloomy valleys of Dévolny, the mountaineer sees nothing around him but crumbling rocks, barren steeps, and scanty crops of barley or potatoes produced, as it were unwillingly, by the stony soil. During part of the winter the sun, which is hidden by the high mountains rising to the south of Valgodemar, describes its daily course without the inhabitants of the valley seeing anything but its pale reflection on the distant summits; and when it appears again in the happy days of spring they greet it as a divinity. The village of Andrieux, built as it is in a basin of the valley, remains for a hundred days

hidden in the shade in the midst of the pale white snow; therefore, who can express the joy which is felt when the imprisoned inhabitants, on the look-out for the first ray, see it dart like a luminous arrow above the crest of the forbidding mountains! In the valleys of the Alps the shivering inhabitants have built nearly all their farmhouses on those slopes of the pasture-lands which are the best lighted by the sun.

Some no less striking contrasts among the inhabitants themselves correspond to the great diversities presented by the outline and trend of the mountains. The finest race of men are found living in the high valleys and on the sides of the Caucasus: most of the inhabitants of the Alps are also remarkable for strength and health, and yet, notwithstanding this fact, Switzerland is the country which, in proportion to its size as compared to the whole of Europe, has the largest number of cripples and other infirm persons. *Crétins* may there be counted by thousands, just as in Savoy, the Pyrenees, and nearly all mountainous countries. Whatever may be the special cause or the various circumstances which predispose

Fig. 189.—Valley of the Plessur.



to *crétinisme* and to the infirmities caused by *goitre*, whether it be the want of aëration in the streams, the absence of iodine in the water which is drunk, or the rarity of the sun's appearance, still it is a fact that idiots and persons affected with *goitre* are to be met with much oftener in gloomy mountain-valleys than in open plains lighted by the sun, open to all winds, and watered by broad rivers. Even lately, many a village of Savoy, such as Bozel or Villard-Goîtreux, had more than a third of the number of its inhabitants composed of idiots with deformed necks. According to Caldas, a tenth part of the population of New Granada living in the narrow space between the wooded steeps of the high summits and the shores of the Magdalena and Cauca and their tributaries, are placed by the sad malady of *crétinisme* outside the very pale of conscious humanity. Thus the most picturesque countries are sometimes inhabited by men in the most degraded state of existence.

Notwithstanding all the varieties exhibited in mountain-nations, it may be asserted in a general way that they are distinguished for courage and firmness. Their broad chest, containing lungs with more ample and numerous cellules than

the lungs possessed by the inhabitant of plains, is filled with both a purer and a lighter air; their eyes, well accustomed to look down from some elevated cliff into the depth of the valleys, and to discern afar off animals cowering in the hollows of the rocks, are bold, and glitter with a piercing lustre; their features are expressive, and their head nobly set on their shoulders; with an even and quiet gait and a firm step they climb the steepest rocks and bound over the glaciers in pursuit of the chamois. Their daily toil is most laborious, and nothing but a courage and perseverance proof against every trial, enables them to obtain the food necessary for their support. In many spots the ground is so steep that it is impossible to make use of animals in cultivating it; there are some mountaineers who plough the furrows with their own hands, and lay down manure to cover over the seed; sometimes, even, they are obliged to carry on their shoulders the fertile mould brought down into the low grounds by torrents and avalanches. In winter they are besieged by snow, and blocked up in their houses, so that frequently they are unable to go from village to village without peril of their lives. It is not, therefore, surprising that at the first approach of cold weather they begin to think of leaving their homes and descending towards the plains, which they speak of admiringly as "level as floors." From every valley of the mountains of Auvergne, the Pyrenees, the Alps, the Apennines, the Caucasus, and the Atlas, troops of mountaineers come down each year; some work for the agriculturists of the lower lands, others follow some trade learned during the interminable leisure of past winters. Actuated by love for their far-distant family, no business comes amiss to them; they deny themselves every pleasure, and, greedily economizing the smallest gains, constantly labour to increase them. No genius is so full of resource as theirs, and by a sort of tacit agreement they have, throughout all Europe, distributed work among themselves, mutually sharing in the various itinerant trades. Among them, the pedlars each have their own peculiar line of business There are some, like those of Venosc in Oisans, who visit the large towns with rare plants from their pastures or minerals from their rocks; others sell tools, engravings, or coarse stuffs; and, lastly, there are some who, as thousands of Swiss recently were in the habit of doing before it was thought a scandal to their country, gave themselves up to the vile trade of becoming a soldier in the service of either enemy or friend.

Nevertheless, although at the first approach of cold the mountaineers emigrate in troops, it is almost always with the intention of returning, like the swallows and storks. Villages which are nearly deserted during the snowy months, are peopled again in the spring, and the petty tradesman of the plains sets himself courageously to the hard work of cultivating the barren soil which covers the rocks. The high summits are too beautiful and too vividly impressed on his mind for him not to love them involuntarily as it were, and when far away from them he is always longing to see them again. In level countries, which he admires so much on account of the evenness of the ground, he looks back with affection to the sloping and rocky fields of his native land, the narrow meadows perched on the edge of precipices, the white snow heaped up on the beds of rock, and the bright summits, which in the morning reflect the first gleam of dawn and in the evening are lit up by the last rays of the setting sun. The inhabitant of level plateaux meets in his migrations with a nature like that in which he has lived all his childhood, and delights in roaming over unlimited space, without even thinking of the steppes where he was born; but the mountaineer can never forget his native valley, which is all in all to him, and if he leaves it for ever he must be forced by the direst necessity. This love of country is the only reason why the people of the Caucasus,

the Alps, and the Pyrenees, who are, notwithstanding, so brave when they have to defend their native land, have never made any permanent conquests in neighbouring countries. After every victory they retire to their own narrow territories, separated from each other by transverse ridges of rock difficult to cross, and while they are dispersing, their vanquished enemies in the plain reconstitute themselves into powerful combinations. The pre-eminently victorious nations are those which inhabit monotonous plateaux or boundless lowlands. The most extensive empire that ever existed was that of the Moguls; it extended from the Vistula to the Yellow Sea, and from the Frozen to the Indian Oceans; like swarms of locusts, the hordes became diminished in their course by battles and sickness, but none the less always kept marching straight on in their rage for massacring men and conquering territory. At the present time is not Russia the great invading power, and does a single year pass without her adding either the territory of a tribe or some fragment of a kingdom to her own enormous empire, already extending over the seventh part of the whole continental area?

Looking at the question in quite a general point of view, it may be said that the countries where the topographical outline acts most favourably on the nations which inhabit them, are the gently undulating lands of the temperate zone, where valleys well watered by streams and rivers alternate with hills, where the landscapes are beautiful, though not with a wild beauty, and the communications are naturally easy. The largest part of France, Germany, England, and the United States present exactly these conditions, and that is one of the principal causes of the comparatively rapid progress made by the various peoples of these countries. Moreover, even in these lands where the race is renewed every day by the intermixture of families, where men and things are constantly mingling, and thoughts are speedily communicated from one place to another, it is easy to notice the contrast which is presented between the inhabitants of each region, according to the difference in the land and local climate. The people themselves never make a mistake, and are always able to mark out the frontier which separates two regions naturally divided. Thus, speaking only of France, the fact has often been recognized, that the outlines of the ancient Gallic *pagi* corresponded pretty exactly with the barriers of the geological formations, and in our time most of these *pagi* would again become reconstructed if an administrative centralization did not roughly oppose the action of natural affinities. Every soil brings forth its own special race; granite, calcareous soils, and even the region of lavas and extinct craters, wide fertile valleys, and the belt of marshes and of sands, are all alike in this respect. The popular name given to each province applies both to the soil and to the man who inhabits it; it explains and sums up the whole of the local geographical facts, and depicts the population itself with its physical features, its manners, habits, trade, and state of civilization. The natural harmony existing between the land and the people is so striking, that when we speak of Touraine, Poitou, Auvergne, La Marche and Limousin, Saintonge and Périgord, the Landes and Armagnac, we might almost fancy that we had before our eyes the aspect of these countries and the features of their inhabitants.

This very variety, this contrast between different provinces, forms one of the most important elements in the strength and prosperity of a nation, provided that these oppositions are not too numerous, and that they do not produce a violent breaking up into fragments and mutual antagonism, but are of a character to blend into one superior unity. Granite, chalk, sandstone, gravel, barren clays, sloping hills, moorlands, and sands mingle their various influences on the populations

which inhabit them, and correct what may be too monotonous in the mind and manners of those who cultivate wide fertile plains. Agriculture may truly be said to be the mother of all civilization ; labourers become attached to the soil from which they derive their own and their children's food ; they detest wars which devastate their fields like a storm, and burn down their cottages as if with fire from heaven ; partaking of the nature of the soil which they cultivate, they are stubborn, patient, and quiet; from father to son, and century after century, they oppose violence and rage with a passive resistance which ultimately tires out the most energetic wills and vanquishes the proudest conquerors. They battle with the very elements themselves, and if a storm destroys their houses or a flood sweeps them away, they will resign themselves to famine, and depriving themselves of the corn on which they feed, will courageously sow it in the too deceitful furrow. These high qualities are among those which are the most necessary in the work of the formation of a nation ; but if the cultivators of the plains had not to undergo the various influences of the more restless populations of the hills, the table-lands, and sea-shores, further progress would ultimately become impossible for them. As regular in their habits as the seasons in their annual course, rooted, so to speak, to the soil like the plants they cultivate, a mere routine would be their only law, their only ideal would be immobility, and their only hope in the future would be the maintenance of things as they were.

CHAPTER LXVII.

INFLUENCE OF THE SEA AND RUNNING WATERS.—TRAVELLING AND COMMERCIAL NATIONS.—ISLANDS AND ISLANDERS.

THE ebb and flow of the waves exercise a great power of attraction on nearly all men, and must certainly be considered as adding a large portion to the population of sea-shores. Savages especially, who always obey their first instinct, yield readily to the fascination which water exercises upon them. In the islands of the Southern Ocean, which are still peopled by barbarous tribes, the sea-shore is the only inhabited part, and the villagers form round the mountains of the interior a ring as regular as that of the banks of coral. It must be confessed that the islanders seek their food in the sea and on its shores, and the coast affords them the greatest facilities for trade and communication. The numberless fish and molluscs which frequent the sea in the vicinity of most of the coasts form an abundant source of food, which legions of fishermen may draw upon without fear of exhausting it. The shore and the waters which wash it form the readiest means of communication for the inhabitants, and allow them to go and exchange their fish for other commodities. We have here the beginning of commerce, and the origin of the modern movement which spreads in all directions across both land and sea, laying hold of the riches scattered far and wide, and circulating them from one to another like, as it were, the life-blood of nations.

These commercial facilities, which are enjoyed by the still barbarous people of many an island-coast, must exercise the same influence to a much greater extent over civilized nations, always anxious to be in relation with one another by the interchange of news and commodities. Thus the small islands of the West Indies, and the scattered isles in the Atlantic, as well as Mauritius and Réunion in the Indian Ocean, are inhabited almost exclusively on their outer edge. In many of these lands the interior remained a long time almost unknown, although the colonists, coming for the most part from colder countries, would have found it to their advantage to seek in the lofty valleys, and on the mountain-slopes, a climate similar to that of their native land. In the same way, on the continent, considerable populations are massed in the vicinity of the coast, and not unfrequently a line drawn from any central plateau to the sea crosses regions increasing in population as it gets nearer the coast. In the interior of the country the people are in the habit of settling on the shores of lakes, which are, in fact, miniature oceans, or along the rivers and other watercourses, which the Chinese so rightly call "the children of the sea." Houses, gardens, and cultivated lands border continuously both banks of every large river in temperate Europe, and

villages and towns are founded at every confluence where a tributary joins the principal watercourse; thus, as is often said, the Seine, the Thames, the Rhine, the Rhone, and the Loire are nothing but long moving streets, uniting one with another the fragments of the immense towns which border their banks from the source to the mouth. The lakes of Constance, Zurich, and Geneva are also surrounded by dwellings and gardens as though with a belt. Towards the eastern extremity of Lake Leman, from Vevey to Villeneuve, the châteaux, hotels, and country-houses connect one village with another, so as to form one splendid city; and certainly the beauty of the scenery, much more than the advantages of navigation, is the point which has made this lovely shore one of the most frequented and populous parts of Europe. The beautiful view of the verdant headlands, of the white shores, and the blue Mediterranean, is the cause why the coast of Liguria for more than thirty-seven miles in length, from Savona to Genoa and from Genoa to Chiavari, has been covered with palaces and marble villas.

Those who live immediately on the sea-shore, and from their dwellings can hear the noise of the waves, have generally a natural instinct to set sail upon them. The unlimited horizon which is spread before them inspires them with the love of space, and the never-ending succession of waves is constantly inducing them to rove over them. It must be confessed that when the coast is totally destitute of ports, bordered by sandbanks and rocks, and exposed to all the force of the waves and storms, the sea-shore populations cannot have that instinctive "soul of iron" which leads them to embark cheerfully on the surge in mere rafts or frail canoes; foreign nations, who are more favoured in the situation of their coasts and the tranquillity of their sea, are the guides from whom they must learn the art of building ships and guiding them over the waves. On the other hand, the inhabitants of coasts washed by waters which are nearly always still, and indented by harbours where vessels can take refuge during a storm, give way to the instinct which attracts them to the sea, and the taste for travels and adventures is gradually developed. When the Spanish discoverers sailed for the first time along the coasts of Central America, they were surprised to meet with trading-canoes "almost as large as their galleys," and capable of carrying about fifty persons. And more than this, off the Peruvian coast the traders in jewels and stuffs were in the habit of venturing on mere rafts, and, allowing themselves to be carried along by the current and driven by the breeze, travelled hundreds of miles along the coast.

Next to the exceptional advantages afforded to maritime populations by a large number of safe ports and absence of storms, the most favourable condition for the development of commerce and navigation among rising nations is the vicinity of an island or archipelago, the dim outline of which is seen over the blue expanse of the sea, and invites from afar as if by some secret magic. In the same way, the timid fledgling flies out from its nest to reach the nearest branch. The islands of the Ægean Sea were the mid-points which attracted the mariners from Asia Minor towards Greece; and Cyprus appeared to the Phœnicians as their first point of progress before they went out into the main sea. The island of Elba, hardly visible from the coasts of Tuscany, forms as it were one stage on the way to Corsica, the Balearic Isles, and the distant shores of Spain; in the same way the white cliffs of Great Britain, which sometimes appear above the Channel like a floating mirage, were a constant fascination, so to speak, to the inhabitants of the opposite shore, and this is the reason why, after having been so often invaded and conquered, she has ultimately become the principal commercial emporium of the whole world.

Islands, those "pearls of the sea," are the features to which the surface of the globe owes some of its most charming aspects; and, thanks to commerce, these islands are likewise the cause to which nations are indebted for a great part of their civilization. As Ritter loved to repeat, it is difficult to imagine how the course of history would have been changed if the islands of Greece, Sicily, and Great Britain had never formed a part of Europe. If the Aryan nations had been deprived of citadels of this kind in which they could, as it were, shut themselves up, and so keep safely the treasures won by their intellectual and moral conquests, they would certainly never have attained the progress which has made the modern world what it is. Steeped in ancient barbarism, they would have remained strangers to one another; although the earth is so small, the whole of its circumference would never have become known, and mankind would still remain unconscious of its full power.

Nevertheless, before the navigation of the main sea had connected one with another all the points on the surface of the globe, islands could not fill any important place in the history of mankind, unless they were situated in the immediate neighbourhood of a continent, and depending, so to speak, on a land with rich plains and a numerous population. Islands standing alone far out in the sea, are like prisons or places of exile to the tribes which inhabit them; even the very facilities they offer for voyages, the stimulus of the wind as it passes, blowing towards other countries, the fascinations of the waves with the mirage moving on them, the indistinct shapes appearing beyond the horizon calling to the mind's eye happy regions far away—all become a cause of inferiority as regards social development, for when the islanders leave their little country to visit some distant land, they seldom return to their native soil. The want of a centre of attraction round which the inhabitants can gravitate, keeps them in a state of isolation and primitive barbarism. Just as in some of the lower organisms in which the head is wanting, life is spread generally over the whole body; but it is not concentrated in any one part, and cannot be very intense. Thus it is that those wonderful isles of Oceania, so numerous, so beautiful, and possessing such a fertile soil and delightful climate, have remained beyond the pale of the civilization of the world; scarcely two centuries ago they were still almost entirely unknown.

At the present time the regions best suited for the progress of mankind are, therefore, the wide continental plains which look out over the sea towards neighbouring islands and archipelagoes. These fertile regions, which also, in most cases, have formerly been gulfs now filled up with marine or fluviatile alluvium, attract a numerous population. These countries with level soils are the spots in which agriculture develops itself, and the adjacent ports are those to which commerce is directed, where commodities are exchanged, and where men learn to know men and thought mingles with thought. Nearly all the mightiest cities are founded on the points where the sea-shore and agricultural regions come in contact; crowds gather there because all the great interests of humanity are there united. By a singular contrast, an agricultural population, which is the most sedentary, and, by its mode of life, no less regular than the return of the seasons, disposed to be the greatest slave to routine, is often found in immediate contact with the maritime class, the most unsettled, quickest in action, and the fondest of travels and adventures. This juxtaposition of men so different in manners is one of the most important facts in the history of human progress.

There are maritime nations whose life is one continuous voyage, having made, as it were, the ocean their home. Thus the Normans, who calle l themselves the "kings

of the sea," were in the habit of sailing from shore to shore, carrying with them terror and destruction, and conquering nations as they passed along; then re-embarking in their light vessels and crossing the vast tract of sea, they discovered the continent of America, which, after their time, remained five hundred years wholly unknown. A similar case is presented by the pirates of the Sunda archipelago, whose countless boats till recently infested the Pacific, and who, although massacred in numbers, continued to multiply as if they sprang from the waves. And where do those who are born on the shores of England pass the greater part of their lives? On the deck, before the mast, amid the rigging and the waves, scanning the clouds and the blue sky. Maritime peoples are always intrepid; they engage in too many terrible conflicts with storms, gusts of wind, and death under its thousand aspects, for them ever to tremble before their fellow-men; they are endowed with coolness and perseverance, for their struggle against the elements must often be a severe one; and, in order to conquer nature in all its fury, they require the courage of reflection more than that of enthusiasm. Their ideas are calm and energetic, but commonplace like the sea they sail upon: they rarely suggest to them either grace or gentleness, but strength and sometimes violence. As a child of the ocean, the sailor presents in his life something like a reflection of the mighty billows on which he has been cradled since his infancy.

CHAPTER LXVIII.

BLENDING OF DIFFERENT CLIMATES.—THE INFLUENCE OF CIVILIZATION ON THE FEATURES OF A COUNTRY.

SUCH, then, from an entirely general point of view, are the influences of various climates on the populations which inhabit them; such, too, are the ethnological contrast produced by difference in zones, continental relief, aspect, and the nature of the soil. Nevertheless, these contrasts rarely present themselves in a distinct and decided manner; it is impossible to trace out the boundaries between nations with a ruler and compass. The influence of winds and currents, the presence of inland seas, the gulfs and promontories of continents, the curves of the mountain-chains, and the countless physical features of the earth, have a constant tendency to alter and intermingle the climates. In many cases even contrary forces tend to balance one another, and consequently the contrasts are weakened and die out. Thus, the ground is low in almost all the cold northern countries, and during the warm season it receives the whole salutary action of the sun; the inhabitants of northern regions, therefore, resemble the mountaineers on account of the severity of the climate which surrounds them, and the people of the plains on account of their low country. Farther south, the mountaineer of the temperate or even the torrid zone may call himself a northerner because he lives in the midst of snow, or a southerner because the rays of the sun descend to him from the zenith, and districts of exuberant richness lie spread before him at his feet. In the same way, if the peak on which he dwells rises from the midst of the sea, he may also be called a child of the ocean, and his character will certainly exhibit some striking contrasts to that of the inhabitant of a mountain situated far in the interior of a continent. The endless varieties in water, air, and situation, and the more or less rapid vibration of luminous and magnetic waves, are constantly modifying the general aspect of nature. Every province, city, and hamlet has its own peculiar climate, and this climate again has nothing permanent about it, and varies every moment. All climatic facts demonstrated by observation blend into one another, and consequently it is impossible to judge of their action on nations except from an entirely general point of view.

And this is not all; nations do not rest for ever on the soil where they were born, but between them and their neighbours there is always taking place a more or less active interchange of isolated individuals and of families. Sometimes, indeed, nations are forcibly united by conquerors who transplant whole peoples; or else, the vanquished go and seek a new country beyond the seas or mountains in a totally different climate. In this case the climatic forces come into action and modify the

primitive type of the man thus removed from his native soil, and substitute for him a new type more in conformity with the nature which surrounds him. This struggle between the past and present, between men and climate, and not the account of the battles of armies and the crimes of kings, are the facts which constitute real history; that is to say, the evolution of man in his connection with the globe.

Moreover, even if nations do not change their country nor intermingle with other nations, their wants and habits become modified with the various changes in the state of society, and consequently the influence of the nature which surrounds them varies century by century. Thus great forests, where the number of inhabitants depends totally on the quantity of game, are no longer suitable to man when he becomes an agriculturist; trees fall under the axe, and the continually widening

Fig. 190.—Villages of Aliermont.

clearings are filled with cornfields; the climate changes and reacts on the populations who crowd into the cleared areas. The reclamation for cultivation of steppes, low and marshy lands, and all formerly desert regions, also results in modifying the surroundings and the people who live there. The great navigable rivers, with their whole network of streams and canals, are scarcely made use of by uncivilized tribes, and, only to adduce one instance, the immense river of the Amazons, the most magnificent track for commerce possessed by the interior of any continent, has scarcely during past centuries exercised any appreciable influence on the development of civilization among the populations on its banks. By means of trade, rivers on the contrary become to civilized nations the principal material agents of progress, until the creation of more rapid and artificial ways of communication have lately diminished the comparative importance of the roads afforded by nature. We find villages grouped along the great highways, even

when the latter do not run through the middle of the valleys but traverse plateaux exposed to the wind and destitute of the water necessary for use; occasionally, indeed, the whole road seems converted into one long street, every peasant desiring to live on the line along which foreign traders pass. Railways, also, have their part in the movement of population, and each station becomes an attractive centre round which all the inhabitants crowd. Beds of metallic ores, deposits of coal, marble, gypsum, salt, and other riches contained in the earth, are also, according to the state of civilization, treasures either unknown or neglected, and are elements either useless or of the highest importance in history. California, a district almost unknown five-and-twenty years ago, has, owing to its gold-mines, become one of the greatest centres of activity on the surface of the globe.

Even the raised outline and the general disposition of countries may be in turn either useful or disadvantageous, according to the various epochs in the life of nations. Thus the barbarous peoples which preceded the present races in Gaul and the other countries of Europe, took refuge in caves among the rocks, or built their huts on piles driven into the bed of some lake. Subsequently, when a continual war of ambuscades and massacres between neighbouring tribes had given place to a somewhat less troubled state of society, the troglodytes came down one after another from their gloomy caves; the lake dwellers left their unhealthy roosting-places and settled on *terra firma* under the shade of the wide-spreading trees: the water of the lakes, which formerly protected them from all attacks, had now become a danger to them by separating them from the land where they found the means of existence. During the terrible iron ages of feudal life, the great lords erected their castles like vultures' nests on the summits of impregnable rocks, grouping the humble cabins of the peasants at the foot of their lofty ramparts; the towns themselves no less than the castles were confined to the crest of some declivity very difficult of access. At that time the primordial care being that of defence, each group of habitations was placed on the summit of some lonely peak, surrounded by walls and bristling with towers. In the south of France, in Spain, on the coasts of Liguria, in Tuscany and Sicily, nearly all the old villages are perched up on the heights, and looked at from below, their crumbling walls resemble fantastic escarpments of the rock; the houses built up on the outer ramparts have no windows but the narrow defensive loopholes; the corner buildings are battlemented and machicolated towers furnished with portcullises; the church built on the highest point forms also the citadel of the village. But in modern times the first requirement is that of labour; the inhabitants, therefore, abandon one after the other their eagle-like eyries and go and settle on the sea-shore, the banks of some river, or the edge of the roads which pass through the plain. Like those sea-animals which get rid of a shell that has become too small for them, they emerge from their picturesque turrets and build themselves dwellings, less beautiful perhaps as a detail in the landscape, but much more healthy and comfortable.

Even in the least civilized countries of Europe the towns have been transposed from their lofty summits and have been established near the sea-coast. On the northern coast of Sicily, every *marina* increases at the expense of the *borgo*, and the old town ultimately becomes a splendid ruin, rising like a mass of rocks on the crest of the lofty mountains. There are still, however, towns containing several thousands of inhabitants situated on mountain-ridges far above any cultivated lands; thus, in Sicily we have Monte San-Giuliano and Centorbi. The former, built on Mount Eryx, formerly sacred to Venus, occupies a narrow plateau 2300 feet above the sea and the plains of Trapani. The town of Centorbi commands the

plain at a height of more than 3280 feet. The inhabitants who cultivate the fields lying at the foot of the mountain are obliged every day to go up and down an endless flight of steps winding in among the rocks and hemmed in by precipices. In front, on the other side of the valley of the Simeto, and at the edge of a stream of lava which has run down from Mount Etna, stand the mansions of Adernó. The clouds which float across from town to town traverse this space in a few minutes; standing on the edge of the cliff of Centorbi, one may even inhale the perfumes of the gardens on the opposite terrace; but to accomplish the distance separating the two localities the time needed is as great, or greater, than that required to travel from Paris to the Belgian frontiers or to the coasts of the Channel. It is evident that a state of things like this must shortly be altered. The citizens, who shut themselves up every day within their ancient walled inclosures, need not now feel any dread in establishing themselves in the midst of tracts

Fig. 191.—Monte San-Giuliano.

of land at present uninhabited. The steepness of the escarpments and the difficulty of access, which were formerly esteemed by them as a privilege when their life was one continual terror, ought henceforth to appear, that which they are in reality, a most disadvantageous loss of time and a deplorable cause for an inferiority in civilization. The summits of lofty mountains will never again be favourite sites for the building of towns, until man has become a lord of the air by being able to steer balloons, and until the most favourable landing-places for him are peaks and ridges.

These successive changes in the more or less considerable adaptation of the earth to the nations inhabiting it, take place no less in respect to the outline of the continents themselves than in the trifling details of local topography. Thus, the numerous bays which run into the coast of Europe, and the peninsulas which project in every direction, and contribute so largely in giving to the people of this part of the world the foremost place in history, are constantly losing in comparative

importance, in proportion as the inland ways of rapid communication increase. It may even be asserted, that in all countries now intersected by railways the indentations of the coast, once so useful, owing to the natural waterways they presented for navigation, have become an obstacle rather than an advantage. Thus, until lately, great commercial ports were necessarily fixed at the land-side of the hollow formed by the shores of a gulf, or else on the banks of the estuaries which run the deepest into the continent; for this position enabled them to receive, by the shortest possible road, the largest possible quantity of commodities and merchandise from neighbouring countries. In our time, owing to the rapid means of communication, this is no longer the case, and maritime commerce tends more and more to take for its starting-place ports situated at the extremity of a peninsula. Every historical progress, therefore, changes the relation of man to the earth which he treads, and consequently the influence of his surroundings is incessantly being modified.

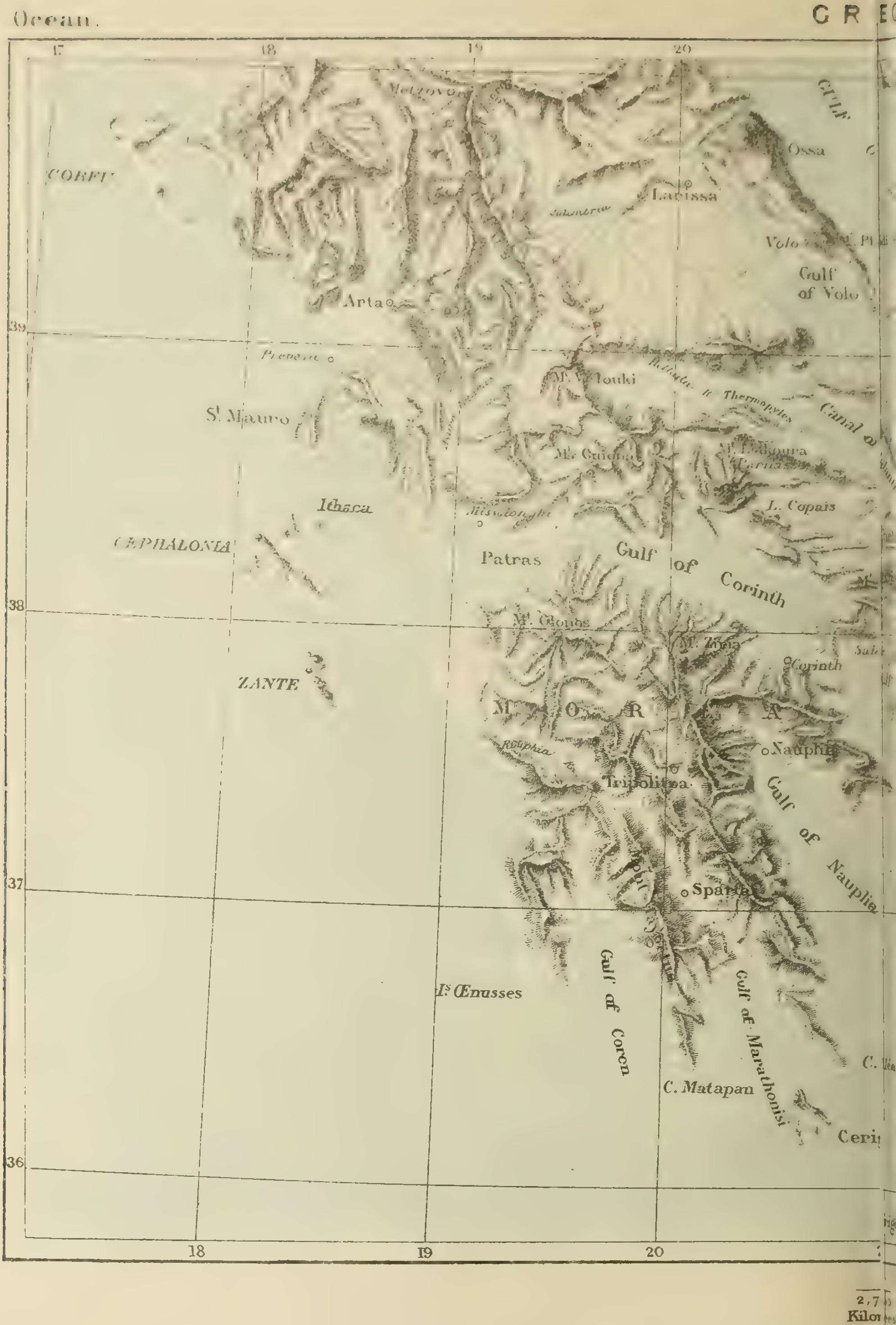
CHAPTER LXIX.

THE COURSE OF HISTORY.—HARMONY EXISTING BETWEEN COUNTRIES AND THE NATIONS INHABITING THEM.

IT is the duty of historians to relate the course of nations across continents and islands, and to point out the incessant action exercised upon them by soil and climate. Every mountain, every headland, every islet, every lake, river, or rivulet plays its part in the history of mankind. Nevertheless, the earth itself and the events which have taken place upon it are too little known for it to be possible yet to attempt a detailed description of the harmony existing between the human race and the globe during past centuries; it is only possible to point out the chief features of the part which the principal regions of the globe have taken in the development of nations.

The vast and compactly formed continent of Africa has not afforded its inhabitants the opportunity of forming relations with other populations of the globe; in the north alone, the Berber tribes occupying the slope of the Atlas facing the Mediterranean, and separated from the rest of Africa by the great desert, have been associated in a slight degree with the movements of European civilizations. With regard to Egypt, whose influence has been so great over Greece and the eastern world, it must be considered as forming a little world by itself, to which the remainder of the continent was as an unknown land. In the vast inaccessible area of equatorial Africa, men were born and died generation after generation, without knowing that other men like themselves lived beyond the boundaries of their country; in their view the entire universe was comprised within the limits of their horizon. Favoured by constant heat and fertile lands, they had not sufficient ambition, and did not tax their ingenuity to render their life more easy. Left to their own resources, they lived as their ancestors had lived; during the course of centuries, therefore, civilization could make but imperceptible progress among them. Almost up to the present time, as is well known, most of the inhabitants of Africa, belonging to totally different races—Kafirs, Hottentots, Congoese, Kavirondos, Ashantis, Fulahs, and Yolofs—have remained in a state bordering on primitive barbarism.

The numerous archipelagos scattered over the Pacific Ocean must, on account of their dispersion, have been as unfavourable to the rapid progress of their inhabitants as was the enormous pile of Africa, on the other side of the world. Previous to the discoveries of modern navigators every island in the Southern Ocean was a small separate world, where, owing to the fertility of the soil and the beauty of the scenery, a rudimentary society was developed; moreover, the facility



Ocean.
G R E
CORFU
Arta
Larissa
Ossa
Gulf of Volo
Prevesa
St. Mauro
Ithaca
CEPHALONIA
Patras
Gulf of Corinth
L. Copais
Corinth
ZANTE
Nauplia
Tripolitsa
Sparta
Gulf of Nauplia
Is Œnusses
Gulf of Coron
Gulf of Marathonisi
C. Matapan
18
19
20
39
38
37
36
10 20 30

ECE.

PL. XXIV.

LIMITED

afforded for navigation in these seas, which are generally smooth and swept by regular winds, enabled the migration of tribes to take place to a very considerable extent. But no sooner were these new connections formed than the old ones were broken off; the savages who had repaired to their fresh country were for ever separated from the former one. In consequence of the fatal isolation of the various groups of people, no great mutual interest and no idea in common can link together all the tribes of the Pacific. This portion of mankind, imprisoned, as it were, in the different islands, has remained broken into fragments never destined to be reunited.

In the east of Asia the inhabitants of the coast of China and the islands of Japan were more fortunate than the islanders of the Southern Sea. In these countries of the Old World the fathers could at least bequeath to their children their industrial skill and their acquirements; tribes could unite with tribes, and nation could instruct nation. The "central flower of the earth," that region vast enough to maintain hundreds of millions of inhabitants, is also in possession of numerous advantages. It slopes gently towards the sea, it is watered by wide navigable rivers, its sea-coast is indented by bays and promontories, and its temperate climate incites to labour by a regular alternation of seasons and crops. The insular part of this region is composed of an archipelago of several thousands of isles, and islets are grouped round the larger tracts of land; the communication between these islands and the continent itself is always easy. Thus the peoples of China and Japan have, by their own inherent energy, attained to a very advanced state of culture, and for a long series of centuries they were probably the foremost among mankind in respect to agriculture, commerce, trade, and practical philosophy. This civilization in the extreme east had, however, no outlets except towards the almost solitary tracts of the Pacific Ocean. On this side the access to other continents and other nations was closed to the influence of the yellow race, and savants have cogent reasons for doubting the fact that, during the course of historic ages, any Chinese emissaries ever crossed the Southern Ocean and carried into the land of Fu-sang, wrongly identified with Mexico and Guatemala, their religion, manners, and architecture.

The tracts of land which extend obliquely across the Old World from Ceylon and the banks of the Ganges to the British archipelago, owe to the favourable form of their outline and the harmonious distribution of their mountains advantages as great as, but different from, those of China and Japan. Descending from the plateau of the Pamir and the circumjacent districts towards Hindustan, Bactriana, and Asia Minor, the Aryan race did not become divided into completely isolated nations. In spite of the lofty mountain-chains of Soliman-Dagh and Hindu-Kush, in spite of the salt plateaux of Persia and the cross ridges of Elburz, Ararat, and Taurus, the communications between adjacent countries were never interrupted, and the industrial and moral attainments of the people did not remain absolute secrets to their neighbours. Whilst each peculiar mode of civilization was worked out in its own special domain, it profited from those which were springing up afar off on other plateaux or on other plains; the myths and the songs of India, bequeathed by the ancient Aryans, were known to the Persians, and the thoughts of Persia flowed back to the Hindus; lastly, the religion and philosophy of both one and the other, modified in their passage through time and space, were mingled and blended with the civilization of the Semitic nations, the Chaldeans, the Phœnicians, the Jews, and the Carthaginians.

On the shores of the Mediterranean, the two countries of Egypt and Asia

Minor, which bound the eastern part of this great sea, are the principal representatives of the first era in western civilization. In these two countries the state of society exhibited the most opposite contrasts in consequence of the variety of races, manners, and climate; but wars, commerce, travels, extensive migrations, and lastly, science, were constantly tending to connect the two poles in the world's civilization. The union of the two contrary elements commenced in the beautiful country of Greece, and then advanced farther on to Crete and the Cyclades, as if to serve as a rendezvous for the ships of Egypt, Phœnicia, Cyprus, Ephesus, and Troas. The ideal of all that the ancient communities had dreamt of as the great and the beautiful was realised in the little peninsula of Hellas, a harmonious combination of mountains, deep valleys, and peninsulas scarcely noticeable on our maps, and yet the part of the earth where, up to our time, the glory of man has shone forth in its greatest splendour. Nowhere else on the face of the globe does the earth assume forms so harmonious, and, so to speak, so living. The mountains, although of no great height, exhibit an outline of such great beauty, that they still retain their celebrity by the side of the giants of the Alps, Andes, and Himalayas; and the names of Monte Rosa, Antisana, and Gaurisankar will never perhaps shine out with the same glory as those of Pindus, Citheron, Parnassus, and Olympus, the abode of the gods. On a diminutive scale, the small country of Greece exhibits, as it were, a summary of all continental features: it has its plateaux, its piles of rock, its mountain-ranges, its valleys and plains, visible and invisible watercourses, lakes, and gulfs; the ancients indeed went so far as to find there both heaven and hell. Its shores are curved into so many gulfs and bays, that the terminal peninsula resembles a dentated leaf floating on the waters Every city had its river, an amphitheatre of hills or mountains, fertile fields, and an outlet towards the sea; every element necessary for the free association of men was there combined, and the neighbourhood of rival cities, equally favoured, kept up a constant spirit of emulation. Thus there never has been seen in the world any groups of republics so proud and so favourable for individual scope of ambition. The little town rendered illustrious by Æschylus, Sophocles, Phidias, Demosthenes, Plato, and many other men of genius, is still, after a lapse of more than two thousand years, the bright centre of history.

At the time when the Hellenic republics were at the zenith of their glory, local civilizations sprang up in Italy, Sicily, Iberia, and Gaul. In consequence of the geographical position of these countries, all the intellectual and moral conquests of Greece and the east turned to their profit. By small degrees, and century after century, an irresistible march of ideas continued its course from the plains of Hindustan to those of western Europe. The revolutions in the history of modern nations are well known; we know also how, after having succeeded in passing through, without extinction, the long and gloomy night of the middle ages, mankind was "born again," owing to a twofold discovery which gave the societies of modern times a definite scope of action. Whilst poets, scholars, and men of science were recognizing in the treasures of antiquity the free thought of Greece and the incisive genius of Rome, Columbus and other navigators were discovering the two continents of America, and thus completing the equilibrium of the globe. From that time the gradual civilization of all nations was assured, both by science and justice, in spite of violence of all kinds, wars, and hideous ignorance. The progress of each nation became that of mankind itself; all the islands and all the continents once separated from one another were united across the ocean and became the common domain of man. At the very time when, owing to the

discoveries of Copernicus, Kepler, and others, the earth, which was supposed to be limitless, was found out to be nothing more than an isolated globe revolving in space, and no longer the centre of the universe, the inhabitants of this inconsiderable planet began to feel the consciousness of their own greatness, and out of this mass of nations and tribes one common humanity began to assert itself.

In consequence of that movement of civilization which, in the Old World spread from east to west, following the course of the sun, the ports of Western Europe, Cadiz, Lisbon, Bordeaux, Nantes, Saint-Malo, London, Bristol, and Liverpool, are like so many conductors from which the electric fluid flashes forth to cross the seas to the American continent. But there the movement must necessarily change its direction. The New World is not, like all great historic countries, placed in a parallel line with the equator; but, on the contrary, it extends from north to south in the direction of the meridian, and, thanks to this transversal position, European emigrants have been enabled rapidly to colonize the lands recently discovered. Italian, Spanish, Portuguese, French, English, and Dutch navigators all found, both to the north and south of the equatorial line, regions with a climate similar to that of their native land, and in both zones they were able to found a "New Spain," a "New France," and a "New England." Added to this, both winds and currents cross the Atlantic obliquely, and bear the mariner towards those wondrous regions of the Antilles and Columbia, where nature, notwithstanding the heat of the climate, exercises so great a fascination over European strangers.

Emigrants from the Old World have thus established themselves all along the coast of the new continent for a length of more than 6000 miles, from the estuary of St. Lawrence to that of La Plata. At the same time, the breaks in the chains of the Cordilleras in the isthmus of Central America enabled emigrants to colonize the western shores, as well as those facing towards China, Japan, and Australia. Thus invading the whole length of both continents, the new comers have been able to go on and conquer the interior of America; they have made themselves acquainted with its vertical outline, with its soils and with its products, which are now better known than the features of a great part of the Old World, and they have founded in these but lately unexplored regions societies allied to those of western Europe. The children of the emigrants have become nations, the power of which has prodigiously augmented when compared to the progress of the mother-country. In these virgin countries, population, manufacture, commerce, public riches, all increase with unheard-of rapidity, and it is an important fact in the opinion of some that the United States of America, to some extent disentangled from the oppressive institutions of ancient Europe, govern themselves by free democracies. The "Utopias" of the Old World have become realities in the New World. America is the laboratory where the European ideal is brought into practical action for the public good.

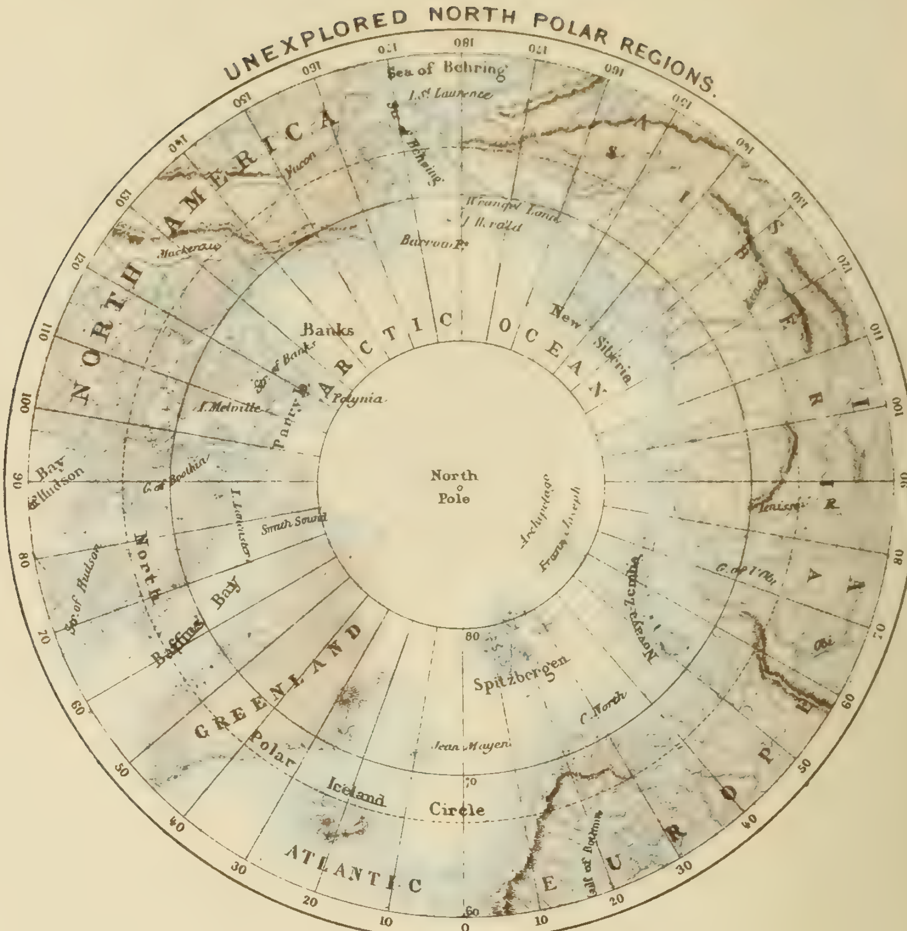
The two Americas present a harmonious counterpoise as regards their continental masses, and from a social point of view exhibit a contrast which may be compared to that of their shapes. The northern portion, situated between Europe and China, is admirably organized to serve as a great thoroughfare for nations and merchandise travelling from the far east to the extreme west. Through it now pass the Pacific railways, which continue on *terra firma* the line of steamboats which, on one side, run between New York and Liverpool, and on the other between Shanghai and San Francisco. In the interior of the northern continent, the inland system of great lakes and the gently undulating plains of the Mississippi afford to commerce and colonization facilities unequalled in any other part of the world.

Nevertheless, the population which forms the United States is almost entirely composed of emigrants of European descent, who have hitherto kept almost entirely aloof from the aborigines and from the race of Negro slaves imported from Africa.

South America is a continent of a more maritime character, and its ports, opening on the great southern seas, serve as intermediate landing-places in voyages of circumnavigation. In the interior, trade and colonization find a province less favourable than that of the northern continent; the mountains there are loftier, the plateaux rise more steeply, the forests are more difficult to cross, the deserts are more inhospitable, and the climate is more to be dreaded by emigrants from distant Europe. Thus, the South Americans have suffered more than their northern rivals from the influence of their surroundings. Without relinquishing their brotherhood with the nations of the Old World, they have gradually become mingled with the natives, and this fusion of races has been the means of introducing those who were once savages into the sphere of modern civilization.

North America may be more European, more characteristic, and more active in its tendencies, but South America addresses itself more to the whole human race: to her belongs the honour of having invited many a still barbarous tribe into the great unity of nations.

Ocean.



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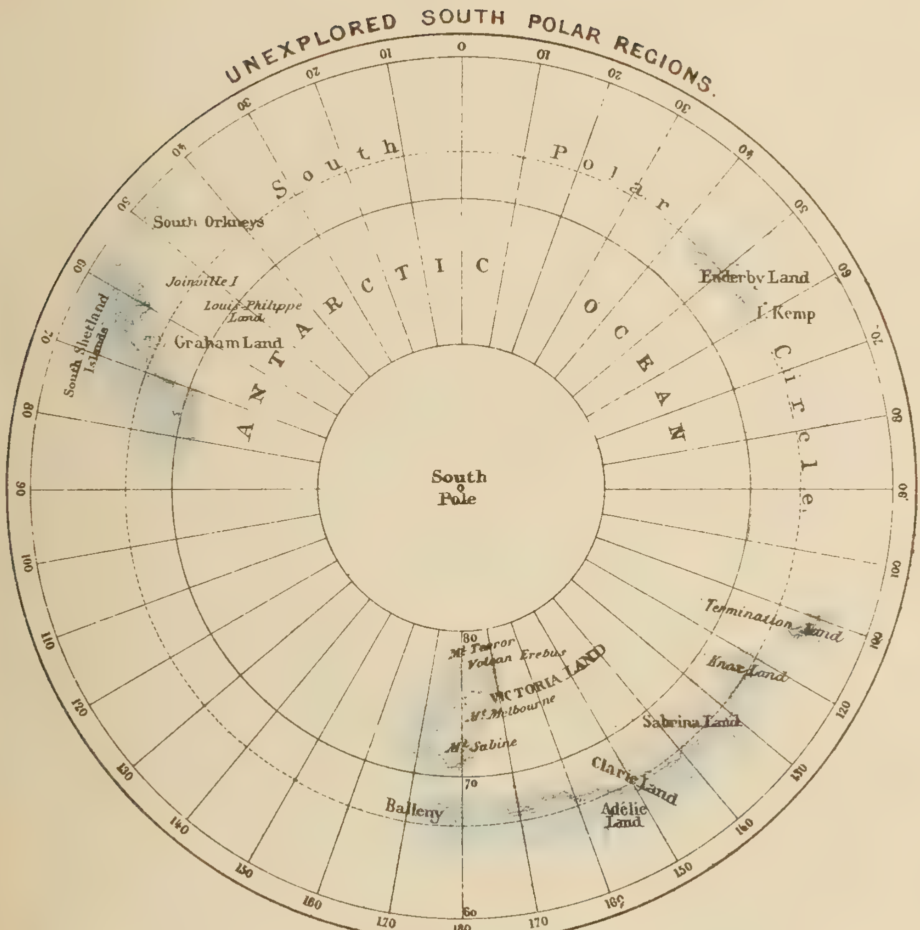

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CHAPTER LXX.

REACTION OF MAN ON NATURE.—EXPLORATION OF THE GLOBE.—VOYAGES OF DISCOVERY.—ASCENTS OF MOUNTAINS.

WHILE society was in its infancy, men, either alone or grouped in small tribes, had to fight against obstacles too numerous for them ever to dream of appropriating the surface of the earth as their own personal domain; they lived on it, certainly, but they timidly concealed themselves in its recesses like the wild beasts of the forest; and their very life was a constant struggle; being continually threatened either with famine or massacre, they were unable to devote any attention to the exploration of the country in which they lived, and those laws which would have enabled them to utilize the forces of nature were still unknown to them. Still, in proportion as nations became developed in intellect and liberty, they learned to exercise a counteracting agency on that outer world, to the influence of which they had passively submitted; they gradually appropriated to themselves the soil on which they trod, and having become by dint of association actual geological workers, they altered in various ways the surface of continents, changed the system of running waters, modified the very climates themselves, and shifted the habitat of the different faunas and floras. Among the works which animals of a lower order have accomplished on the earth, the islets built up by the coral-animal may, it is true, be compared with the works of man as regards their extent; but these constructions are uniformly continued century after century, and never add a new feature to the general physiognomy of the globe; we always find similar kinds of reefs and similar tracts of land emerging from the ocean like beds of fluviatile or marine alluvium; whilst the works of man are incessantly being modified and give the greatest diversity of aspect to the earth's surface, renovating it, so to speak, with every fresh advance of his race in knowledge and experience.

The principal of all the conditions which will some day enable man to completely transform the surface of the globe, is that he must become fully and entirely acquainted with it and traverse it in every direction. Formerly, the savage or barbarous tribes, living entirely separate from one another, formed nothing but chimerical ideas as to the territories lying beyond the narrow boundaries of their own country; they fancied they saw there nothing but an empty and limitless space, a gloomy and formidable world peopled by monsters, but where man himself could not live. All the most remarkable features on the surface of the globe remained utterly unknown to them; the inhabitants of the plains imagined the whole earth to be one great level tract of land, whilst those of mountainous regions pictured it to themselves as a succession of narrow gorges, cliffs, and summits. In the same

way it appears that the Zuñis, who lived far from the sea-coast in the deserts now called New Mexico, were ignorant of the very existence of the ocean ; on the other hand, numbers of the islanders of the South Sea were totally unaware that vast continental masses, extending over an area of many thousands of miles, divided the seas into separate basins. According to the testimony of Franklin, the Esquimaux learned with astonishment, that towards the south lands existed perfectly free from ice, and under the equator the ignorant inhabitants of the banks of the Amazons innocently imagine that their enormous river flows all round the world.

In proportion as, by means of trade, travel, and even warlike expeditions, nations came to know the territories belonging to one another, they banished the idea of monsters into the mysterious spaces extending beyond the boundaries of the explored world ; the sphere of knowledge increased simultaneously with the regions traversed, and the fanciful beings, such as gnomes or giants, who were supposed to retreat either towards the north or the south, bore away with them many of these superstitions and erroneous ideas. Thus the Greeks, who are represented to us by their mythology as contending in the earliest ages against centaurs and dragons, in the time of Aristotle and Plato fought only with men like themselves ; and they localised the fantastic figments of their childish imagination at points many hundreds of days' journey away on the other side of the Ganges and the columns of Hercules, in the burning deserts of Libya or near the Hyperborean mountains. Thus, in the middle ages, and even down to modern times, our maps of the world, like those of the Chinese and the Japanese, represented all unknown lands as inhabited by monsters ; but every new discovery made by travellers contracted the domain of fable, and quite recently the last mythical beings of geography, the tailed Niam-Niams, have finally been made to disappear from the centre of Africa.

Since the time when man first went round the world—that is to say, nearly four centuries ago—explorers have no longer had to venture into any region completely unknown : all they had to do was to connect with one another the lines of travel already traced out on the surface of the globe. This network of innumerable intersecting lines covers nearly the whole of the great continental masses and extends over all that portion of the sea comprehended between the two polar circles ; only towards the north pole, and on the opposite side of the earth in the antarctic regions, there still exist areas extending over a space of 2,800,000 and 8,700,000 square miles respectively, which frozen seas and mountains of ice have, up to the present time, kept intact from any exploration. Those spaces which still have to be explored at the two poles form nearly one seventeenth part of the surface of the earth—that is to say, a tract equal to about sixty times the area of France. In those regions there is still a very considerable extent of unexplored land and sea, and even in our days a few pusillanimous geographers have expressed a fear that these districts will remain for ever unknown. Captain Cook, the brave navigator of the Frozen Antartic Ocean, asserted that no one had or even could approach any nearer to the pole than he had done. Pigafetta, also, in his account of the great voyage which he took with Magellan, gives as his opinion, "that in the future no sailor would be bold enough to brave the dangers and fatigues of another circumnavigation of the world." It must certainly be confessed that fifty-six years elapsed before another sailor, Drake, brought to a happy termination a second voyage round the globe ; in the present time nothing is thought of such voyages, so often are they accomplished.

The energy with which the explorers of the polar regions have undertaken and are always ready to recommence their perilous voyages across the ice is a sure

guarantee of their future success; for though the obstacles remain the same, the experience of sailors and the resources of science are ever increasing. The discoveries which have still to be made in the centres of the vast continents of Asia, Africa, South America, and Australia, cannot fail to be accomplished before very long; for most of the difficulties which impede travellers are of the moral order, and will gradually disappear, thanks to the progress of commerce and civilization. The horrible trade which makes the white man so justly abhorred in the centre of Africa, as well as in the basin of the Amazons, will soon come to an end; the tribes once appeased will welcome the explorers and supply them with guides; groups of colonists, advancing by stages across continents, will form links of connection between the districts inhabited by civilized races. Every year the spaces of land we still have to examine and trace upon our maps are diminishing in size, and hundreds of heroes, numbers of whom are destined to die in obscurity, are still further endeavouring to narrow them. The most extensive surface which up to the present time has remained untrodden by the feet of European explorers, is that part of the African continent which is comprised between the sources of the Nile, the Congo, the Ogoway, and the Benue.

When man at last becomes acquainted with the whole surface of the globe of which he styles himself the master, when Columbus's saying is realised, "*El mundo es poco*," (the world is small!) the great geographical work will then be, not to explore distant lands, but to thoroughly study every detail of the country which we inhabit; to make ourselves acquainted with every river and every mountain, and to point out the part taken by each portion of the terrestrial organism in the life of the whole. This work, at the present time, is the task to which most of our savants, geographers, geologists, and meteorologists are specially devoting themselves, and important societies are being formed in every direction in order to push on local explorations. These societies address themselves most of all to the mountains which rear their glittering summits far above populated slopes, where no mortal foot has yet surmounted the snow. Every year several of these hitherto inviolate peaks are successfully scaled by travellers, who point out to their friends the road they must follow in order to surmount them; these small spots elevated into the glacial regions of the air can no longer escape the investigations of man any more than the vast tracts in the arctic and antarctic zones. The English may lay the chief claim to the honour of having given the first impulse to the desire for exploring so many lofty summits. It is now a hundred and twenty-five years since Pocock and Wyndham discovered, so to speak, Mont Blanc. Since that memorable epoch individuals of the English nation are still those who, surpassing in zeal and intrepidity the very inhabitants of the Swiss Alps, and even the Savoyard, Italian, and French mountaineers, have made the most frequent ascents of Mont Blanc and the other giants of the Alps; it is the English, too, who have investigated with the greatest ardour the Mer-de-Glace and the various glaciers of the western continents, and have explained to us the actual topography of the almost unknown ranges of Pelvoux, Grand-Paradis, and Viso; it is they, too, who, by the foundation of the first Alpine Club, have since given rise to a great number of societies of the same kind in the different countries of Europe. Lastly, they have already established at Lahore a "Himalaya Club," in the hope of being able some day to surmount in turn all the lofty summits of Central Asia, which are double the height of the European giants.

CHAPTER LXXI.

RECLAMATION OF THE EARTH BY CULTIVATION.—ANCIENT AND MODERN IRRIGATION.

LONG before man had made the soil of the earth his own by science he had commenced to adapt it to his use by cultivation. The various tribes of hunters and fishermen, like the nomad shepherds, did nothing to modify the aspect of the earth, and if their race had become extinct, no vestige of them would have pointed out their existence on the surface of any continent; but as soon as families permanently settled down where esculents might be grown for food, and learnt how to plant trees and to sow seeds and fruits, the work of transformation was commenced. Every spot of the earth where plants useful to man, such as cereals and fruit-trees, had taken the place of other vegetable products which were cut down by the axe or cleared by burning, has become a centre round which cultivation has spread from place to place, till in the present time, thanks to the hundreds of millions of men who unceasingly labour in order to draw out the productive forces of the earth, immense tracts have completely lost their primitive aspect. The total extent cultivated by the hand of man, and divided into fields with regular boundaries, may be estimated at 2,900,000,000 acres, that is to say, about one tenth part of the continental surface. It must however be confessed that by far the greater part of this vast tract of land is worked rather by a system of extortion than properly brought into cultivation.

The population of the earth, at present estimated at 1,600,000,000, might be easily doubled, increased five or even tenfold, without any fear of scarcity, were the soil everywhere tilled to the best advantage.

In countries which possess soils of a naturally salubrious and fertile nature, and are not yet inhabited by a numerous population, selection is the only difficulty experienced by the agriculturists, and the soil which they cultivate is of that kind which produces abundantly without any need of fertilising it by manures. Thus, in the United States, where there are more than 700,000,000 acres of unoccupied ground still at the disposal of the citizens, the colonists cultivate little else but alluvial plains, the land bordering rivers, and valleys watered by running streams. On the other hand, in the countries of the ancient world, where the crowded population is beginning to feel the want of rich soil, a great variety of soils, which anywhere else would be despised as unfruitful, is made to form a part of the domain of agriculture, and sooner or later becomes covered with crops. There is no soil that man, impelled by necessity, and having at his disposal the enormous resources

which are afforded him by the combined efforts of science and industry, cannot transform into fertile fields. By means of drainage he draws off the hurtful water which chills the earth and rots the roots of plants; by means of irrigation he brings on the land at the proper time the water necessary for the development of sap and tissues; by means of manure he enriches the soil and nourishes the growing plants; and by these and other improvements he changes the very nature of the land. Agriculture, which was formerly carried on at random, is tending more and more to become a science, and it will become a perfect science when the laws of chemistry, natural philosophy, meteorology, and natural history are thoroughly understood.

Among the great agricultural undertakings already accomplished solely through the sheer perseverance of the peasant, without even the assistance of the resources of modern skill, there are some which are truly admirable. For example, what could be more wonderful than the hillocks on the banks of the Moselle and the Rhine, or the hills of Provence, Liguria, and Tuscany, which, from the base to the summit, are encircled by wide concentric stages, each of which is covered with crops of vines, olive-trees, or corn? The pickaxe and spade have broken up the loose rocks, and the débris have been used to construct this huge staircase of walls, each of which, like the terrace of a garden, keeps back the vegetable soil and prevents it from crumbling down the declivity of the rock. Should a storm breaking over the mountain overthrow their walls and devastate their pieces of ground, next day the peasants are to be seen hard at work reconstructing the stages, while others—and the women generally perform this task—toil up from the foot of the mountain bringing back basketful by basketful the precious mould which had been carried away by the storm. How contemptible the celebrated hanging gardens of Babylon must appear when compared with these prodigious monuments of human labour!

The slopes of the Mediterranean volcanoes also present remarkable instances of what may be done by the persevering will of the cultivator. On the very slopes of Etna, the summit of which rises far into the region of perpetual snow, more than 300,000 inhabitants have their abodes. The soil of the fields, which are shaded by multitudes of fruit-trees, is composed of nothing but lava and ashes; but hard and daily work has transformed it into a garden which is the wonder of Sicily. The peasants set stubbornly to work at every rock, and step by step have reclaimed them and transformed their rough uneven surface into vegetable soil. When the mountain breaks forth into an eruption, and vomits out lava over the crops and the villages, agricultural labour is merely stopped for a time. Families religiously preserve their rights of property, just as if the property itself had not disappeared; then after the lapse of few or many years, as soon as the cooled lava is covered here and there with patches of lichens, the agriculturist sets to work in order to utilize the smallest crevices of the rock which offer facilities for vegetation. Certain compact lavas, particularly that which destroyed a portion of Catania in 1669, can only be broken up by a singularly slow process, and in order to cultivate the upper layers of the scoriæ during the course of the same century, it was necessary to pulverize them and mix them with fertile mould; nevertheless, industry ultimately succeeded, and gardeners planted there shoots of the cactus, which grew up very quickly and hid the reddish-coloured earth behind the impenetrable thickets of their thorny leaves, which shine in the sun with a metallic brilliancy. Fig-trees creeping along the ground insinuate their long roots into the interstices of the rocks. In certain spots even the vine thrives and bears fruit on these hard scoriæ, which look almost like

blocks of iron. Other kinds of lava, on account of the friability of their texture, and the quantity of ashes which are blown on to them by the wind, are adapted for a rudimentary kind of cultivation in the space of a few years. Of this kind are the lava-flows of Zaffarana, which burst from the bosom of the earth in 1852 and 1853 ; in the hollows the inhabitants of the villages planted some brooms and furze within five years after the eruption. But whether the scoriæ of lava be either friable or hard they will nevertheless ultimately become transformed into vineyards and gardens. As persevering as the ants, who seem never weary in rebuilding the heaps destroyed by the feet of those who walk over them, the peasants of Mount Etna begin again from century to century their persevering work, and after every flow of lava which covers their fields, they lay out new meadows no less verdant than the gardens which have disappeared.

Among all the agricultural works which have changed the aspect of the earth, channels of irrigation are those which, in past ages, have been most magnificently planned and carried out. The Egyptians, blocked up by the sand of the desert, and setting their hearts, so to speak, upon the mud of the Nile from which they believed their ancestors had sprung, made irrigation one of their great sacred rites. Their reservoirs which were dug out for the management of the flood-waters must have required as much labour as the useless ostentatious pyramids. In Lombardy and Tuscany, also, the general irrigation of the country, under the direction of syndicates, was practised with great skill, and the grandest names both of artists and savants, such as Leonardo da Vinci, Michelangelo, Galileo, and Torricelli, are associated with the history of this portion of the art of agriculture. In the present time this work is being carried on with great activity in all the countries of the south of Europe, and in many other regions of the world which are liable to suffer from aridity. Before they emerge on to the plains, nearly all the mountain-streams of Piedmont, Provence, Roussillon, and Mediterranean Spain, are almost entirely drawn off on to the fields, and only during showers or the melting of the snow the stony beds are filled up with muddy water which the thirsty land very soon absorbs. Great rivers, such as the Po, the Nile, and the Durance, which are utilized for irrigation, diminish in quantity of water every year ; and if the ambition of agriculturists is realised, they will ultimately disappear altogether.

Moreover, at the present day we are no longer contented with surface-water for the moistening of the earth. By means of borings, man seeks to obtain the water which flows in the depths of the earth, and to force it up to the surface in order to irrigate his plantations. This has been most successfully carried out in Algeria, either with a view of increasing the extent of existing oases or to create fresh ones. No doubt this operation might likewise succeed in other countries where underground streams are hidden beneath the arid soil. And this is not all ; that water which is diverted from its natural course or is made to gush forth from the bowels of the earth, acts upon plants not only by supplying them with the necessary moisture, but also by means of the various fertilizing matters and manures which it carries along with it. On the fields over which it flows it spreads the alluvium derived from formations of different natures, and thus tends to blend various soils, a process which is very advantageous for vegetation; by the process of "warping" it changes naturally poor ground and renders it excellent for cultivation.

CHAPTER LXXII.

THE CULTURE OF MARSHES.—DRAINAGE OF THE GROUND IN THE COUNTRY AND TOWNS.

BY means of irrigation, the agriculturist succeeds in reclaiming arid tracts of land, such as the sands of the Landes, the clays of the marshes, and rocky cliffs; by means of drainage, he adapts to his use flooded lands which had never produced anything, and converts it into the most fertile soil, and the name of "nursery gardener" is now applied to those gardeners who, in the vicinity of our large towns, are able to make the largest quantity of vegetable substance spring from the smallest area of ground. Every advance which mankind has made either in Italy, the plains of France and Germany, on the saturated soil of Batavia, or in Great Britain, would have been impossible but for the draining and sanitary improvement of the ground; every spot where civilization has partially retrograded, as may be seen round Carthage, Syracuse, and Rome, is marked by fresh encroachments made by marshes once reclaimed. At the present time, when the work of colonization is carried out on so large a scale, the principal work of the pioneers in Mitija, on the shores of the Mississippi, on the coasts of Columbia, the Guianas, and Brazil, in the Sunda Isles, and on the coast of Africa, is to consolidate the soil and to purify the air, so as to add a fresh domain to those which mankind has already fully appropriated. This is a work which costs a considerable number of lives every year: in many a plain now rich with harvests the number of peaceful agriculturists who have perished in their toil is greater than that of the soldiers who have fallen on fields of carnage, such as Leipzig or Sadowa. But everything gives way before patience, and sooner or later, thanks to the increase of the human race, to the progress of its industry, and to the combination of its forces, the marshy banks of the Amazons, the lagunes of Paraguay, the wet districts of Lake Chad, and the Sunderbunds of the Ganges and Bramahputra, will ultimately become healthy countries. In all climates alike this work of improving the earth is being carried on. In Norway, where the area of arable land was in 1866 only 1000 square miles, the agriculturists are now reclaiming every year 40 square miles of the marshes and fjords.

At the present time the plan proposed by scientific men is nothing less than that of establishing below the surface of the ground a circulatory movement of waters, analogous to that which is naturally taking place in the air and on the surface of the earth by means of clouds and rivers. The water rises from the sea in the form of vapour, and floating through space is precipitated in the shape of rain and returns towards the ocean through streams and rivers; but this water

which is flowing down towards the great reservoir of the sea, is on its way appropriated by the agriculturist, who divides it into channels and then into small streamlets for irrigation, and these are distributed not only on low-lying fields, but also on the sides of hills and mountains, and even over high plateaux. The water, being thus divided into innumerable branches, sinks into the soil over the whole surface of the district, where, like a second rain, it refreshes and nourishes the roots of the plants. Its work of usefulness is then terminated, for if it remain for any length of time in the ground its action will become fatal to vegetation; it will drown and rot the small rootlets and close up the pores through which the outer air penetrates.

Thus, irrigation may be fatal where the subsoil does not possess, like the surface, a perfect system of channels relieving the ground of any superabundant moisture. The water filters drop by drop into the small drainage pipes, then the different streamlets unite into one larger drain, and gradually increasing in its course, the invisible rivulet flows from pipe to pipe, and discharges either into a river or into the sea. Such is the immense work of subterranean drainage which agriculturists are now undertaking in a multitude of localities, and the result is that all the hydrological and climatic conditions of the soil are slowly but surely modified. The damp countries of civilized Europe, especially Great Britain, are the places where the drainage of land is carried on to the greatest extent; in England alone the length of all the drain-pipes placed end to end must be estimated at not less than 6,200,000 miles or 250 times the circumference of the earth. Unfortunately the conflict of private interests and the lack of enterprise and wide views in most of the proprietors of the soil, have prevented this work being accomplished according to any general plan; each one works at it in his own field without troubling himself about his neighbour, and too often these partial systems of drainage result in swelling the streams and changing the lands situated below them into marshes. Sooner or later the immense undertaking involved in the aëration and drainage of the soil will have to be systematically recommenced, so as to be adapted to the whole area of every fluviatile basin. Then, and then only, shall we be able to compare the artificial system of drainage with the natural network of running streams; the whole of the partial circulation established in each country by human labour will correspond with the general circulation produced in the air and on the ground by the rotation of the globe.

Large towns especially are the chief places where subterranean drainage has in our time begun to be carried on in the most systematic manner. It is well known that rivers and streams of pure water are used in our towns as receptacles for all kinds of filth. If, for instance, we take London, that great city consisting of over four hundred thousand houses, and in its widest extent containing nearly five millions of inhabitants, connected by endless streets to numbers of rising suburban towns, which seem to increase under your very view, and if we pass down the marshy banks of the wide Thames, which flows between such immense swarms of humanity, we shall see how that nation of the world who knows best how to appreciate nature, has also polluted her. At the ebb of the tide when the river, with its slow and dark stream, flows seawards, beds of semi-liquid mud filled with putrefying rubbish were till recently laid bare, emitting into the air their nauseous exhalations. At the flow, when the body of water, being arrested in its progress, gradually rises and ascends the Thames, the islands of mud ceased to be visible, but most of the unclean rubbish borne down by the ebb was again carried up by the tide; a kind of to and fro motion was thus constantly shifting these impurities

up and down stream under the eyes and noses of the inhabitants. But since the completion of the present drainage system the nuisance has been greatly abated, and mainly confined to the lower reaches of the river.

The rivulets and even the small streams which fall into the Thames, after having flowed through a portion of the province now become London, have long ago disappeared under the streets and the houses, and are become nothing but sewers. That which has taken place in the vast English city has been equally the case in all the spots where men are most densely accumulated. Paris has thus changed the Biévre, which flows down to it so pure from the hills round Versailles, into a mere ditch of liquid filth; sometimes, when the water is low in the Seine, a solid mass of impurity may be extracted from the liquid, equal to nearly a fortieth part of the whole flow of the river. Everywhere we find that the groups of men, whom rivers have drawn to their banks, have commenced by polluting the water, and have often rendered it unfit for drinking purposes or even altogether injurious to health. The forcible and gross names which the inhabitants of the South of France have given to most of the rivulets flowing through their great towns, give us some indication of the hideous state of uncleanliness which these streams have now attained.

Having thus deprived themselves of the drinking water which nature had placed at their disposal, although the quantity would, indeed, in most cases have been insufficient, the inhabitants of many towns have been compelled to replace them by spring-water or streams artificially conveyed to them at great expense. This is one of the principal problems which we have to solve in respect to the well-being of the rapidly increasing populations, which are crowded in our great cities. In former days mighty Rome, who made the conquered nations of the whole earth work in her behalf, diverted, by means of aqueducts, the water running from all the adjacent mountains and made it flow down into her public squares, where it jetted out in abundant streams from a multitude of fountains, and was collected in wide basins. At the present day, there are very few modern towns which receive a quantity of water so considerable, comparatively speaking, as that which flowed into ancient Rome; most young and rising cities, growing as it were at random, have not, in their foolishness, as yet understood what are their most imperious requirements, and are still deficient in the necessary supply of water. Their attention is, however, being more and more awakened as to this point, and the nineteenth century will not close before most of our large towns are abundantly provided with all the water necessary both for drinking purposes and for cleanliness. The hydraulic works of this description which have been already undertaken round Marseilles, Paris, Glasgow, New York, and Chicago, exceed all that the Romans have done in this respect, not only by their beauty as works of art, but by the length and capacity of the aqueducts, and especially by the skill with which the engineers have succeeded in overcoming natural obstacles. New York is built upon an island. Nevertheless pure water is made to flow into it from the mainland, passing over the Hudson through a gigantic arched syphon. Chicago is built at the mouth of a marshy river and by the side of a lake, the water of which is constantly polluted by the ships anchored along its shores. Consequently Chicago draws its water at a point a mile and a half from the shore, by means of a large tunnel dug under the bed of Lake Michigan; it requires a submarine stream for its daily drinking-water!

With regard to the discharge of sewage water—a point scarcely if at all less requisite than the supply of pure water—London, the greatest city in the world,

is the one which has become the model city in this respect. The total length of its sewers is 80 miles, and they have been built large enough to carry away from the town 2300 millions of cubic yards of water and filth every 24 hours, that is about 28,000 cubic yards a second, a larger body of water than the Mississippi pours down on an average towards the Gulf of Mexico. But the effect of these subterranean rivers is not merely to draw off the sewage water, which until lately tainted the Thames. It is proposed to utilise them in irrigating a tract some 150,000 acres in extent, which it is hoped will thus afford abundant pasturage for about 100,000 milch cows, sufficient to supply butter and milk for nearly the whole of the vast metropolis. "Thus," states the report of the Board of Health, "completing the great circle of life, death, and reproduction." Like some prodigious animated being, London is incessantly absorbing water by its aqueducts, and food and commodities by its railways; and the refuse, which it rejects and carries far away through its sewers, is made available for reproducing the nourishment necessary for its enormous appetite.

CHAPTER LXXIII.

THE DRAINING OF LAKES AND INLETS OF THE SEA.—LAKE COPAÏS, THE LAKE OF FUCINO, THE SEA OF HAARLEM, THE ZUYDER ZEE.—POLDERS.—THE PURIFICATION OF SALINE MARSHES.

EMBOLDENED by the reclamation of marshy lands, agriculture sought fresh conquests, and soon attempted to take possession of the beds of lakes, and of low grounds occasionally covered by the sea-water. From the earliest antiquity great works of this kind have been undertaken; twenty-two centuries ago, in the time of Alexander the Great, Krates the engineer devoted himself to the task of entirely emptying the lake of Copaïs, in Bœotia. During a long series of dry years this basin was often reduced to a few pools of marshy water, and tiny rivulets crept over the plain between the reeds and rushes; but, on the contrary, in rainy seasons it was a fine lake with an area of several millions of acres, and was constantly swelled by the torrents which came down from Helicon and the other mountains in the vicinity. The water was separated from the sea by a wide rampart of calcareous rocks, and found no means of outlet except by certain deep fissures or *katavothra.* Krates straightened these so as to facilitate the flow of the water; but since this epoch they have become again obstructed, and the projects which have been formed in later days for restoring the work of the ancient Greeks have been all in vain.

Modern engineering skill has been more fortunate on the soil of Italy in resuming and finishing a great work of drainage, which the Romans were not able to bring to a happy conclusion. The lake of Fucino, situated fifty miles to the east of Rome, near the towns of Avezzano and Celano, occupies the centre of a circular range of hills in the Apennines, formed like a crater, the slopes of which are covered with dwellings and cultivated fields. Sometimes floods inundated all the country round, and destroyed the crops; and afterwards, when the water ran off, the air was filled with poisonous miasmas; the difference between the levels shown during high floods and at low water was not less than thirty-nine feet. During the reign of Claudius, thirty thousand slaves worked for eleven years in digging out a channel 6151 feet in length across Monte Salviano, in order to draw off the largest portion of the water into the Liris, and thence into the sea. It was fully believed that the work had been happily achieved so as to last for centuries, like the tunnel, about one-third the above-named length, which had been dug more than four hundred years before from Lake Albano, near Rome. All that now remained to be done was to open the flood-gates. The emperor, vain as cruel, had prepared a splendid *fête* upon the Lake; nineteen thousand gladiators, embarked in

two opposing fleets, were to figure before him in order to celebrate the inauguration of the canal. The slaughter took place, but when the order was given to empty the lake, the water, mixed as it was with blood, refused to flow out. Narcissus and some other courtiers, enriched at the expense of the public treasury, had doubtless kept back the money which was necessary to complete the works of consolidation. Later, at different periods, the canal was cleaned out, and rendered a certain amount of service at times. At last, in 1854, the works were energetically resumed, the outlet was enlarged, and a mass of water amounting to more than a thousand millions of cubic yards, which the lake contained above the level of the tunnel, was emptied out, the marsh fevers ceased their ravages, and cultivation gradually advanced towards the centre of the former lake-basin.

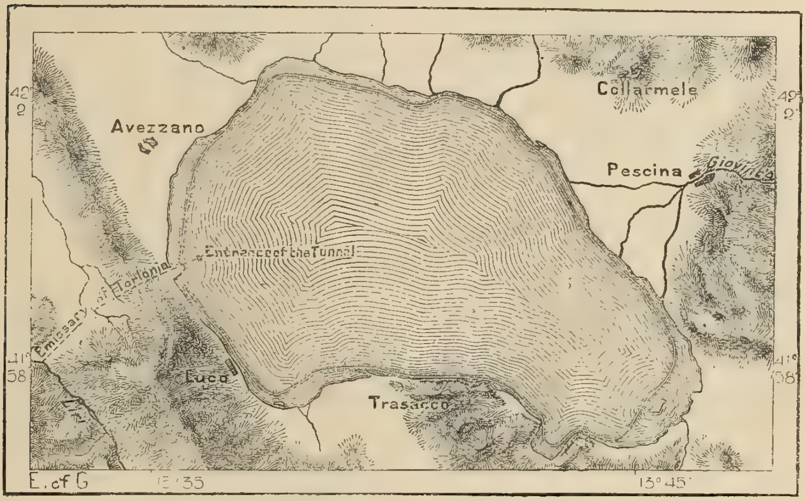
Among the great modern undertakings in the way of drainage, the most important, on account of the obstacles which had to be overcome, and also of the prospect which has been derived from it, is, however, that which has entirely recovered and added to the mainland the whole bed of the lake known by the name of the Sea of Haarlem. This lake, as it appears, began to form in the thirteenth century, and since that date continued constantly to increase at the expense of the cultivated land and villages surrounding it. In the sixteenth century it had acquired the dimensions of a sea, and naval combats were fought on its waters, between the Dutch and the Spaniards. Every great tempest added to its extent, and during the winter of 1836 a violent west wind caused it to reach the very gates of Amsterdam. The banks round it, which were kept up at a great expense, were of no avail in holding back the water, which rose incessantly. Then it was that, looking

Fig. 192.—Lake Copaïs.

forward to imminent danger caused by the encroachments of the Sea of Haarlem, the resolution was taken to endeavour to drain it dry. It was thirteen miles long and six miles broad, with an average depth of thirteen feet, and contained a body of water estimated at 950 millions of cubic yards. In addition to this, it was also necessary to reckon on the water resulting from infiltration and from rainfall, which would make its way into the lake during the time whilst the drainage operations lasted; this was estimated at about 260 millions of cubic yards of water. In 1852 this immense work was completed, and three enormous steam-engines, pumping together at each stroke of the piston as much as 260 cubic yards of water, had discharged the whole of the Sea of Haarlem into the ocean. At the present time the only work the steam-engines have to do is to clear the former basin of the lake from the water accruing by infiltration and rainfall, or, during the dry seasons, to furnish the water necessary for irrigation. In fact, the soil at the bed of the lake, having been for so long a time deprived both of air and sun, could only be gradually changed into arable ground capable of absorbing easily the rain-

Fig. 193.—Lake Fucino.

Scale 1 : 160,000.



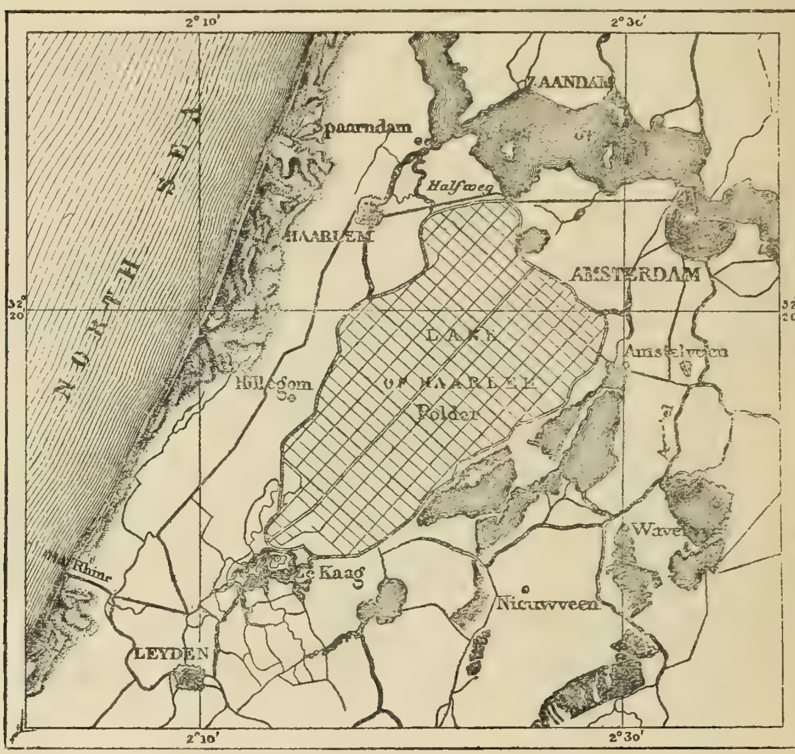
2½ Miles.

water, and giving it back in the shape of vapour. It was necessary, says an author, to bring machinery to its aid, in order "to complete its education." The clayey and peaty bed of the lake, which, since the process of emptying out and draining had sunk about eleven inches, is now changed into fine cultivated lands, and the public wealth of Holland has been thereby increased to a very great extent. The emptying and drainage works cost £1,320,000; but the "polders," the appearance of which, it must be confessed, is singularly wanting in the picturesque, already represent a value of over £12,000,000, although originally sold by the State for £800,000. The yearly revenue now derived from them by the proprietors is three times greater than the purchase money.

Is not, however, the greater part of Holland nothing but a vast Sea of Haarlem, which the energetic and persevering people of the Low Countries, by their labour, continued from age to age, have succeeded at last in laying dry? The very sight of the level soil, every clod of which has been so often turned over and over, and

of the defensive dikes which divide the country into an infinite number of parcels, shows how an entire nation—in conflict with nature, and acting somewhat in the mode of a geological force, never ceasing for generations in its endeavours towards this great work—has succeeded in reconquering the soil of the country, and rendering it fit for cultivation. It is probable that sooner or later the vast gulf of the Zuyder Zee will be also recovered from the ocean. This work, proposed in 1849, would certainly have already been commenced, but for the fact that the greatest part of the bed of this gulf consists of fine sand, which is difficult to bring into cultivation. When executed it will have reclaimed about 500,000 acres of fertile

Fig. 194.—The "Polders" of Haarlem.



soil at an estimated expenditure of £16,000,000, including roads, canals, dikes, and other indispensable works.

The ground reclaimed centuries back, either from the sea or from marshes, does not present any geometrical regularity in the network of its canals and draining channels. In former times the engineers were not so bold as they are in the present day, and in the formation of their canals utilized all the small natural watercourses and passed round all the scarcely dried rising grounds in such a way, that their ditches assume a winding and sometimes wavy line. As a whole, this network of intersecting liquid veins presents a form somewhat analogous to the great and small vessels which follow out their ramifications in organized bodies. The land more recently reclaimed does not show in its system of drainage these meandering and picturesque lines; it is cut across by its canals with a mathematical regularity. At regular intervals rectilinear and parallel canals have been dug, which extend from one end to the other of the whole space enclosed by the dikes.

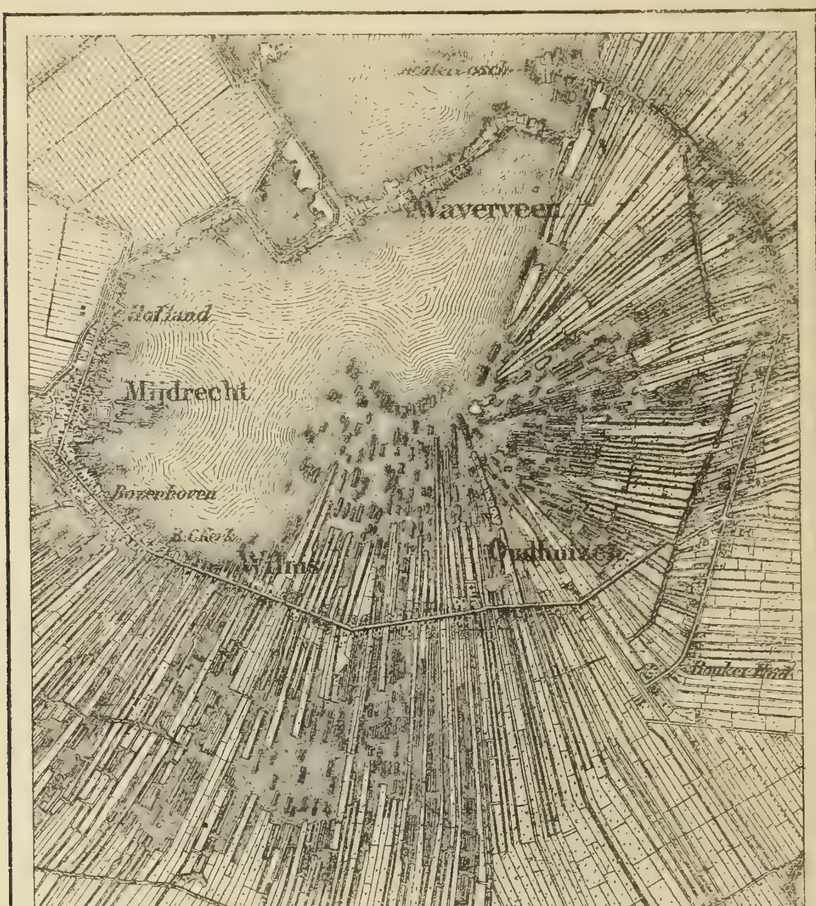
These canals are crossed at right angles by main arteries of the same width, and thus the whole country is divided into great parallelograms, which are again sub-divided into small parcels of land by narrower canals and ditches, both equally rectilinear; the farmer is obliged to use boats either to visit his farm, to carry his manure, or load back his crops. All round this vast chessboard of cultivated ground extends the canal which surrounds it and receives the drainage water of the *polder*, being protected by strongly made dikes against inundations coming both from without and within. At one time it was the wind which was employed to raise the surplus water of the *polder*, and discharge it directly or by means of canals into some one of the rivers of Holland. The drainage pumps were worked by those picturesque windmills which the Dutch painters exhibit to us in all their landscapes; but at the present time the larger *polders*, for which it is indispensable to assure a constant and regular flow of drainage, are provided with steam-engines which incessantly pour water into the outside canal.

When the lakes which have to be dried up are so deep that it is impossible to reclaim them for cultivation by mere ditches and canals, the only course left is either to empty them boldly, as the Sea of Haarlem was emptied, or else it is necessary to work for centuries in elevating above the surface of the water certain small islets which will ultimately be joined one to another. The brave agriculturists of the Low Countries, feeling that the lapse of ages made them one with their descendants, did not shrink from undertaking this task, which would some day be completed by their grandchildren. In the first place, they made dikes round the banks of the lowlands, which they could drain with comparative ease, and afterwards, when the alluvium had caused a bed of mud to show itself above the water, they lost no time in taking possession of it, and in raising and draining it, giving to it an elongated form which would subsequently facilitate the labour of digging canals when the pool was changed into a *polder*. Several generations beforehand they foresaw what would be the general arrangement of the land, which at present lies under water, and every shovelful of mud that was brought up from the bed of the pool, every pile that was driven down into the ooze, was made to take its part in the continuation of the work. We are enabled to form some idea of the wonderful patience and methodical spirit with which the farmers of the Netherlands carry on their labours, if we travel over the Zuyder *polders*, and numerous other districts which are now fields, although still in part consisting of lakes. The houses in the villages are built in a long circular street on the top of dikes which surround the lake, and the fields, divided by canals, spread out like the sticks of a fan round the centre of a sheet of water. According, however, to the outline of the lacustrine and marshy spots which are subjected to the operation of drainage, the *polders* assume other shapes of equal regularity; they form squares, stars, and concentric polygons. If seen from a balloon, some parts of Holland, with the innumerable grey lines of their ditches and canals, would recall vaguely to the mind's eye the surface of certain chemical bodies crystallized in radiating or parallel needles. The astonishing regularity of the landscape is undisturbed, save by the masses of buildings in the large towns, the parks which surround them, and the roads and railways crossing the canals in an oblique direction as they emerge from the cities.

The Dutch are so much accustomed to recover land by means of canalization, that they often go to work in the same way in cases where the ground might have been brought under cultivation by other processes; and even in the tropical climate of Java, they have transformed the environs of their cities into small editions of

Holland. On the east of the Low Countries, the inhabitants of Friesland, Ditmarsh, and Schleswig have had to come in conflict with the same difficulties, and, like the Dutch, have been able to triumph over them, and to convert into *polders* vast tracts of inundated ground. On the east coast of England, the shores of Suffolk and of Norfolk, the estuaries of the Wash and the Humber, are bordered by fens of very great fertility; and the encroachments of agriculture on the ocean-domain take place in these districts on a very extensive scale. In the same way, in Belgian and French Flanders, in the neighbourhood of Ostend, Dunkirk, and

Fig. 195.—The Zuyder Polder.

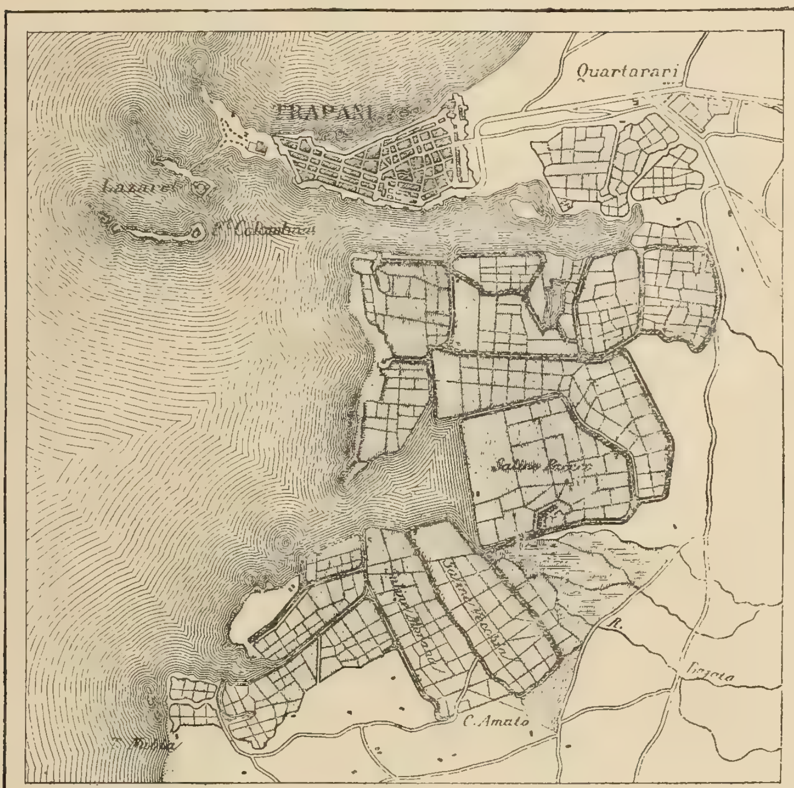


Calais, the *watteringhes* have been reclaimed from the North Sea. Near Etaples, the inland sea of Ponthieu or Marquenterre has been changed into fine cultivated fields; and between the mouths of the Loire and the Charente the marsh lands are everywhere protected by dikes and intersected by ditches which are crossed by the country-people, both male and female, by means of their long leaping-poles. To the south of the Gironde there are also some "small imitations of Flanders," and in the Landes the Lake of Orx has been recently drained by the same kind of operation as that adopted in the Sea of Haarlem.

In Holland and all the other countries bordering on the North Sea it is only

necessary to throw up dikes round, and to drain the marshy tracts by the sea-shores, and they will be converted into fertile fields, fit after a few years for any crops which the climate allows. On the coasts of the Mediterranean, Caspian, and other seas, another course has to be adopted. In these districts the tracts of ground which have formerly been inundated by salt-water always remain more or less saturated with salt and are unfitted for any permanent course of cultivation. Thus, instead of turning them into cultivated fields, it is found better worth while in many spots to utilize them as salt-marshes. The salt water, conducted from one pond to another, evaporates in the sun, and ultimately leaves on the bed of the last compartment a thin layer of salt, which the labourers collect and pile up in great

Fig. 196.—The Salt-works of Trapani.



pyramids on the edge of the roads This manufacture assumes its chief importance on the shores of the western Mediterranean; certain salt-works on the sea-shore there produce from ten to twenty thousand tons every year.

What is the cause which produces the contrast between the natural fertility of the *polders* of Holland and the sterility of the ground recovered from the sea on the Mediterranean coasts? The cause must first and foremost be sought for in the greater or less supply of fresh water which washes the soil. On the shores of the North Sea the air is naturally moist, and the quantity of rain-water which is showered down upon the country is very considerable. The porous earth is constantly washed by the rain, and all the soil on the surface is gradually carried away, so that almost as soon as they are surrounded by dikes the cultivation of

the *polders* may be commenced. It must be confessed that, on the shores of the Mediterranean, the saline portions of the ground are likewise dissolved and carried into the subsoil; but in consequence of evaporation, which is very active in this climate, the water from the bottom ascends gradually through the porous earth together with the salt which it holds in solution, and then evaporates, leaving on the surface a crust more or less thick of saline matter. A reciprocating motion is thus established between the surface and the deeper strata of the ground; the rain causes the salt to descend and evaporation causes it to rise up again, whilst the sea-breezes add an additional thin layer of salt to that which already exists on the soil. Pools of almost fresh water and a saline efflorescence cover in turns the surface of the ground; the plants which the labourer would fain endeavour to cultivate are either drowned by water or else burnt up by salt.

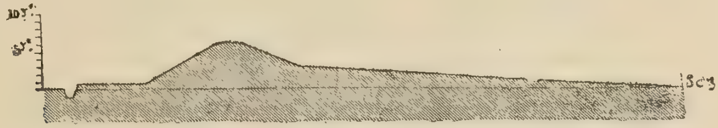
Fortunately, the knowledge of the evil has led to the discovery of the remedy. It is found that rain carries the saline matter down into the subsoil, and therefore that great temporary inundations would bring about this result with a much greater degree of certainty. After having established at a suitable depth a complete system of drainage, it is only necessary to turn for some time a branch of a stream over the land to be drained; the salt in the upper stratum will immediately be dissolved and carried down into the subterranean conduits, being ultimately removed by this powerful lixiviation into an external basin where the emptying pumps are worked. The frequent application of this process of washing succeeds at last in cleansing from all saline matter the land that was most saturated with it; and agriculture thus gains a new and fertile field for its operations. Moreover, this means of reclaiming low, salt tracts on the shores of the Mediterranean is no longer a matter of mere speculation, as it has already been put in practice. Not far from Saint Gilles, on the smaller branch of the Rhone, certain tracts have been purified from the salt which they contained and converted into cornfields. More recently, immense tracts of land near Frontignan, once perfectly useless, have been gradually purified by the little stream, Roubine de la Vie, which supplies pure water by a lateral cutting, and then lower down in its course receives the drainage-water charged with saline matter. According to M. Dupouchel, the inventor of this system of purifying the soil, it would be possible to deal thus with a great part of the south coast of France, and to create a complete border of magnificent *polders*, covering a surface of more than 250,000 acres, and representing an agricultural value of from 20 to 30 millions of pounds. And what even would such a reclamation as this be, when compared with those which may some day be made in all the countries which border on the sea and on salt lakes? At present the quantity of salt annually recovered along the whole of the Mediterranean seaboard is roughly estimated at about 1,300,000 tons. The salines of Crimea alone yield from 100,000 to 400,000 tons, according to the requirements of the surrounding populations.

CHAPTER LXXIV.

DIKES ON THE SEASHORE.—POINTS OF DEFENCE.—POINTE-DE-GRAVE.

THROUGHOUT the whole region of *polders* scattered along the coasts of the ocean, the immense labours undertaken with a view of draining certain tracts of land must necessarily be completed by a system of marine fortifications, for it is necessary to defend at any cost against the force of the waves and the shock of the tempest, the cultivated land which has been reclaimed with so much difficulty. The whole of the sea-boundary of Zealand, Holland, Friesland, and the other "low countries" on the coast of the North Sea, is bordered by a continuous rampart of dikes, about 25 to 35 feet high, and 150 to 300 feet broad at their base. All these embankments are constructed with the utmost care, with their longer slope, on which the waves have to break, towards the sea; the bank itself is armed against the surf by a trellis-work of posts, fascines, and even by a woven texture of straw over which the waves glide, being changed into foam. On the land side the dike has a steeper slope and is bordered by a small drainage ditch, in which is collected the water which soaks through the earth or is thrown by tempests over the top of the embankment. Should the sea, when it is very rough, destroy one of these

Fig. 197.—PROFILE OF A SEA-DIKE IN FRIESLAND.



ramparts, a portion of the *polders* is inundated; but at a certain distance another dike rises, and beyond this, others which keep back the flood-waters. During the continuous labour of more than a thousand years the country people, ever on the watch to snatch a slice of land from the ocean, have never ceased constructing embankments round every reef of mud left bare by the sea-water, and the defensive ramparts are thus connected all round the outside of the district; in some spots where the deposit of the ooze from the sea takes place rapidly, the districts of the interior are separated from the shore by a quadruple or quintuple girdle of embankments. It must be confessed that, on the occasion of fearful storms, the recollection of which ever dwells in the memory of the inhabitants, the sea has again taken possession of wide tracts of land, in exchange for those which man has snatched from its domain; but at the present time the Dutch engineers, the

most experienced and most skilful in these operations, are making regular encroachments on the seas surrounding them. It has been calculated that, on the average, the area of the Low Countries increases at the rate of seven acres a day, or 2470 acres a year; this is somewhat more than a four-thousandth part of the whole territory. The length of the dikes placed end to end would extend to several thousands of miles; they much exceed the embankments along the borders of the Mississippi and its tributaries.

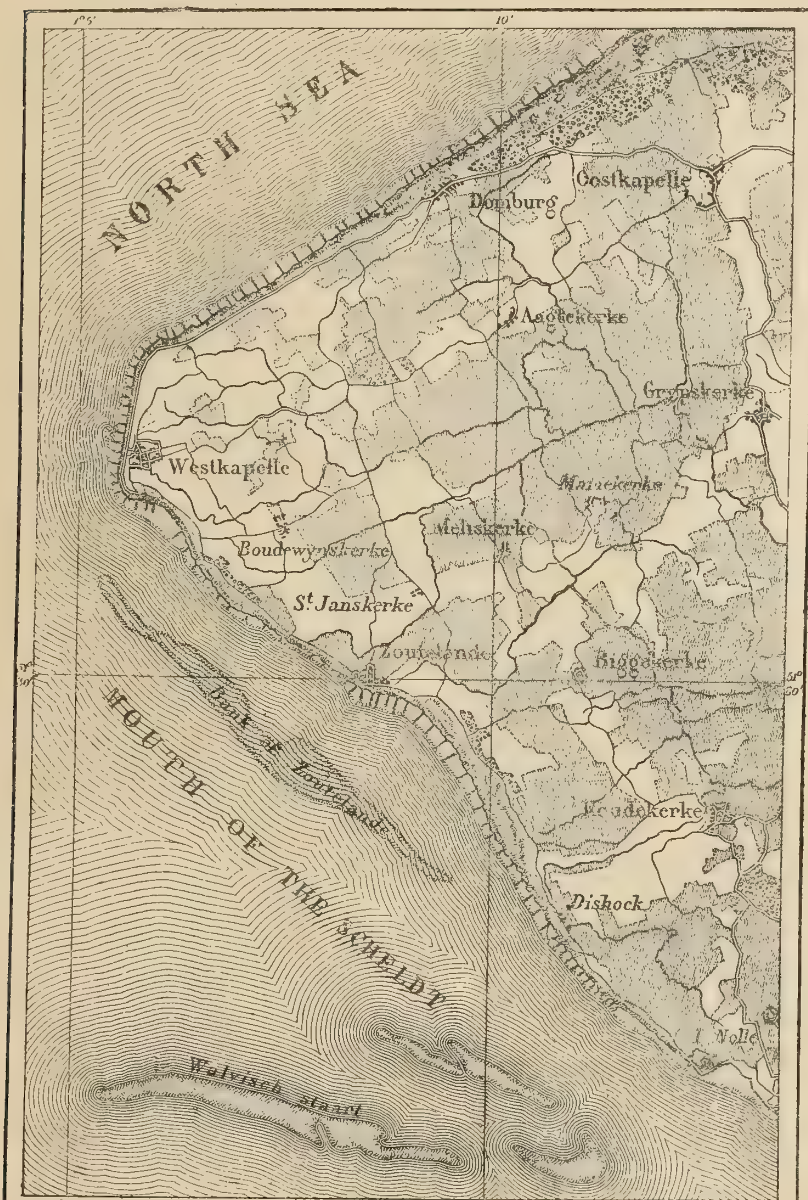
Those spots where the currents, waves, and winds blowing from the sea, all work together to break through the shore-line, are the places where man is compelled to show proof of the greatest perseverance and the most inventive genius in his strife with the elements. In the Isle of Sylt, on the coast of Schleswig, the idea was formed of making the sea itself a joint-worker in the construction of the dikes which were to stay its progress. All along the sea-beach palisades were set up in two parallel rows, about ten or twelve yards distant from each other.

Fig. 198.—The Dikes of Uithuizen.

During a tempest, the waves charged with sand dash over the fascines, and let fall among the branches the sand and shingle that they carry; the latter is heaped up between the two lines of palisades, and soon a long artificial *dune* is raised along the edge of the sea, affording protection to the land inside. Means of this kind cannot, however, be successfully made use of on every coast, and especially on various points of the shores of Holland, which seem to sink down below the sea level like a leaky ship. The town of Westkapelle, in Zealand, was devastated by the waves which opened a wide inlet through the rampart of *dunes* on the shore. The houses were rebuilt farther inland, under the protection of an enormous dike which closes the gap between the sand-heaps; but this embankment has entailed such an enormous amount of labour in its maintenance and repair, that a bulwark of solid copper might have been erected at less expense. In a similar way, owing to a large opening being forced between the *dunes* on the shore, the Isthmus of Petten, situated on the western coast of the peninsula of Holland, was threatened

with complete destruction; in this case, Amsterdam and all the shores of the Zuyder Zee would have been left without protection against the waves of the sea. But by means of various works, dikes and stake-barriers, the inhabitants ultimately succeeded in giving solidity to the shore. At the present day the inhabitants

Fig. 199.—The Embankments of Westkapelle.

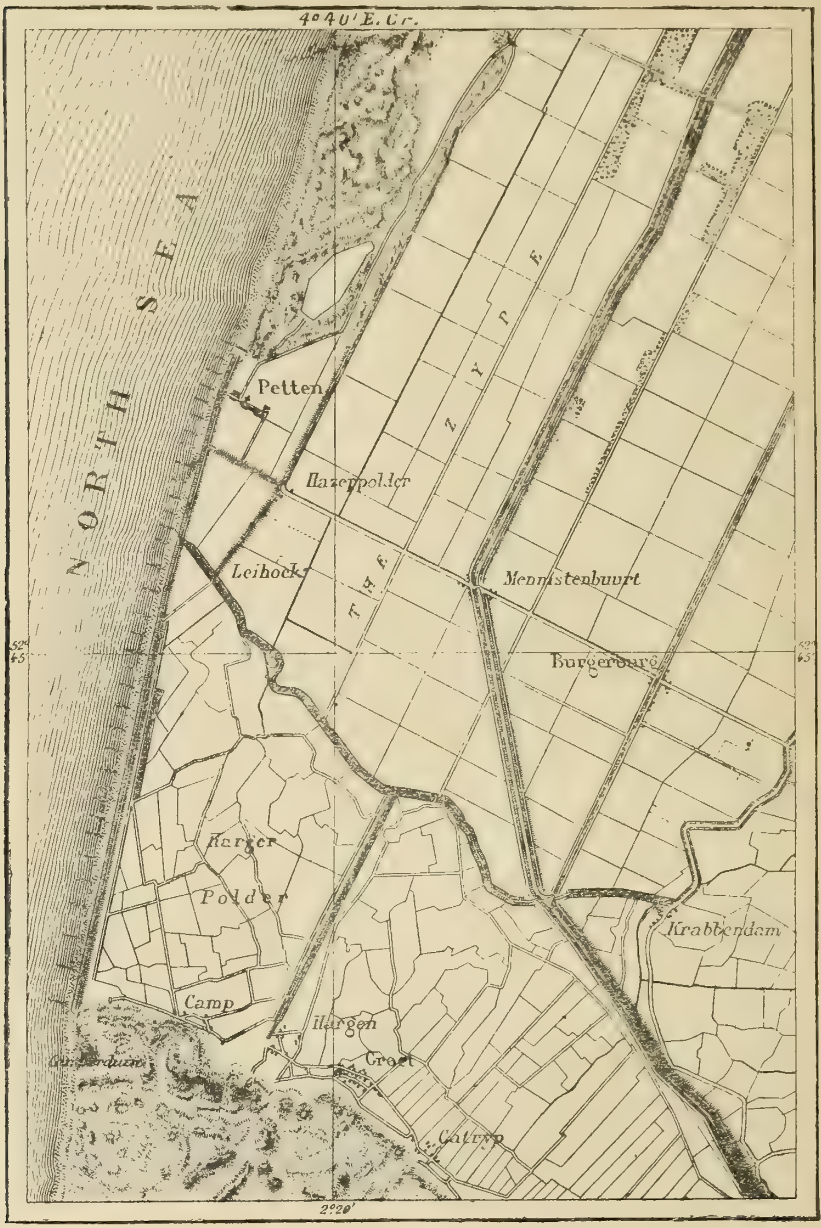


of this part of Holland have no longer anything to fear from the inroads of the sea.

In France, Pointe-de-Grave, at the mouth of the Gironde, is one of those spots which may most aptly be brought forward as an instance of the violence of the sea,

and as a locality where man has to strive his hardest with the breakers. It is known exactly how far the sea-beach has shifted its position since the year 1818; at this date Pointe-de-Grave extended into the Gulf of Cordouan 2400 feet to the north-west beyond its present position. Between 1818 and 1830 it receded 600

Fig. 200.—The Embankments of Petten.



feet, or 50 feet each year. From 1830 to 1842 it lost annually nearly 120 feet. Between 1842 and 1846, when the engineers were at last engaged in their conflict with the sea, the waves advanced 630 feet in their triumphant march, that is more than 150 feet in one single year. Now, the sounding-line shows a depth of more

DEFENSIVE WORKS AT POINT DE GRAVE IN 1860.

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than five fathoms at a point where the outline of the shore might once be seen. It has been found necessary to pull down, and rebuild farther inland, all the buildings which once stood at the extremity of the point. The ancient fort which defended the entrance of the Gironde has been demolished by the waves, and during the low equinoctial tides cannons may still be seen shining in the wet sand. In 1846, the width of the strait which separates Cordouan from the peninsula of Bas-Medoc had increased exactly one-tenth in the period of twenty-eight years.

Whilst the sea was thus eating away the extremity of the peninsula, at the same time it was endeavouring to pierce into its base. At the narrowest point of the isthmus which joins the *dunes* of Grave to Medoc, the waves worked energetically in scooping out a wide bay known under the name of the bay of Huttes. From 1825 to 1854 the sea-shore receded 1140 feet. During the period of low tides the isthmus of Huttes, which extends between the ocean and the salt-marshes of Verdon, was still 1320 feet in breadth; but at the time of flood-tide this breadth was reduced to 960 feet, and when the waves are lashed into fury by a storm, they throw their foam to the very summit of the sandbanks on the narrow isthmus. Another five and twenty years of an advance as rapid as this, and the Atlantic would succeed in breaking through the fragile bank of sand which is opposed to it by the mainland, and overflow into the marshes, converting into an island the present peninsula of Grave. The Gironde would join the sea by a second mouth, and the present generation might contemplate geological phenomena similar to those which took place when the island of Cordouan was detached from the mainland and gradually changed into a shoal. It was necessary to prevent this, not only as it would have caused the ruin of all the property on the peninsula; but also as a matter of far greater importance, it was necessary to preserve for ships the precarious shelter afforded to them by the roadstead of Verdon, which is already too much exposed to the violence of the west winds in consequence of the constant erosion of Pointe-de-Grave. It was therefore with good reason that the resolution was adopted of entering into a contest with the ocean, and to arm the peninsula, by means of bulwarks, against its assaults.

In order to protect the shore of the gulf, thirteen parallel jetties from 500 to 600 feet long were constructed. These jetties were composed of stiff clay faced with stones firmly fixed, and were defended against the onset of the waves by fascines and piles; they thus offered resistance both by their elasticity and the cohesion of all their parts. Nevertheless all these jetties were not strong enough to hold their own against the sea in stormy weather. First one gave way and then another; so it was resolved to construct a dike parallel to the shore of the bay of Huttes. During the course of the work the waves and storms often assailed the dike and broke through it at various points; but the workmen, successfully fighting against the billows, were able to close up the breaches and to solidify those parts of the bulwark which had been broken down. In March, 1847, after five years spent in an incessantly renewed contest between man and nature, the dike, 3600 feet long, was at last finished and seemed to forbid the breakers any future approach to the *dunes*. The engineers had begun to congratulate themselves upon their work, and were fancying that they had vanquished the ocean, when a few weeks after the works were completely finished a terrible tempest from the south-west raged in the gulf against the coast of Medoc; the last jetties of the bay were swept away like bits of straw, and the greatest part of the enormous dike was broken through, carried away, and annihilated by the all-powerful billows.

In order to check the inroads of the sea, they scarcely had time to construct,

at the inner curve of the shore of Huttes, a kind of pyramid composed of enormous blocks of concrete, each weighing several thousands of pounds. The gigantic steps of this embankment presented a firm resistance to the assaults of the waves, but as there was nothing else employed for the defence of the shore, the ocean soon showed threatening signs of turning it, and continuing beyond it its work of erosion. The shore of the bay of Huttes receded 80 feet, and two wells which had been dug and lined with stonework in the sand of the *dunes* were laid bare to their very base, and stood up like towers on the edge of the waves, presenting themselves as strange witnesses to show the inroads of the sea. The victory had been fought for by man at great cost, but the sea had remained the conqueror, and thousands of pounds lay peaceably buried under the waves. At last it was resolved that, instead of building a mere water-wall, as had been already done, a regular breakwater should be raised to oppose the billows; this was to commence at the southern extremity of the bay and to stretch across to the north, joining the immovable rocks of Saint-Nicholas. In front of this rampart, cubic masses of concrete weighing several tons each were thrown down, so as to form a kind of gentle slope the length of which was equal to ten times the height of the breakwater. Added to this, the wicker-work embankments, being threatened by the incessant burrowing of the *teredo*, were gradually replaced by strong dikes in stonework. The ocean has not as yet broken through this last barrier, and hopes may be entertained that henceforth the same respect may be shown towards it. Nevertheless, the waves seem inveterate for the destruction of the obstacle which restrains them, and use in turn both force and stratagem to attain their end. They displace the blocks of concrete, they sweep away the sand, they make crevices in the masonry, and pushing forward in every direction their labours of sapping and mining, they untwist the fascines so carefully bound together, and sometimes leap over the construction itself, and boldly attack the shore beyond.

At Pointe-de-Grave the conflict between the sea and human power was scarcely less sharp. On that portion of the sea-coast which stretches away for a mile and three-quarters to the south of the cape, fourteen jetties, similar to those adopted in the bay of Huttes, were pushed out into the sea. At the point itself, instead of the jetty, there is substituted an embankment running out 400 feet, composed of natural and artificial blocks of stone dropped down into the water from trucks. The extremity of the embankment, which is under water, is prolonged for some distance by heaping up rocks which are dropped from small vessels when the weather is favourable. So great, however, is the violence of the waves, that these rocks, weighing on the average two tons each, are very frequently shifted by the meeting of the ebb and flow of the tide and are drifted out into the offing. When subjected to the shock of the waves, the embankment itself has sometimes cracked here and there across its whole width, and the workmen are from time to time obliged to reconstruct the slope, to fill up the cracks with stonework and to consolidate the blocks of stone whose equilibrium is threatened. Sometimes, also, the water hollows out caverns under the rocks at the base; it is then necessary to go down at low tide in order to stop up the excavations, to strengthen the approaches, and to prevent the advance of the enemy.

As if enraged at the insurmountable obstacle opposed to it by the powerful breakwaters at the point, the sea has spent its fury on the tongue of sand which extends behind the jetty. Attacking the bank on the rear, the waves incessantly increased the small bay of the fort in the direction of the river, and between 1844 and 1854, whilst the sea-coast remained almost in a stationary condition, that

which faced the Gironde receded 1600 feet, that is to say, 160 feet a year. A few years more, and the dwindled peninsula would have been completely broken through, the lighthouse and the other buildings would have been swept away, and the jetty, detached from the mainland, would become nothing more than a rock beaten by the waves. It was therefore necessary at any price to exclude the inroad of the sea by constructing at the angle of the fort a breakwater similar to that which had been already built up in the bay of Huttes. A breakwater has since been erected in this spot, and at last a period of mere surveillance has succeeded to the contest of twenty years' standing between man and the ocean. The works, now happily completed, have ultimately contradicted the general superstition which attributed to the waves a force irresistible by man. The force of oceanic billows, like that of the aërial waves impelled by tempests, can be exactly estimated in tons or even in pounds; and in order to overcome their brute force, all man has to do is to oppose a superior resistance which can be measured by his calculations. It is, moreover, probable that a more profound knowledge of hydrological laws will some day enable him to utilize this very force which at the present time it is so difficult to resist; the ebb and flow of the tide, the waves of the tempest sometimes so terrible, will also find their work cut out for them, and their action when well directed will become an instrument in the hand of man.

CHAPTER LXXV.

NATURAL AND ARTIFICIAL WAYS OF COMMUNICATION.—SEA-SHORES, DESERTS AND SAVANNAHS.—RIVERS, CANALS, AND RAILWAYS.—BRIDGES AND VIADUCTS.—THE CUTTING THROUGH ISTHMUSES.—THE SUEZ CANAL.—THE ISTHMUSES OF CENTRAL AMERICA.

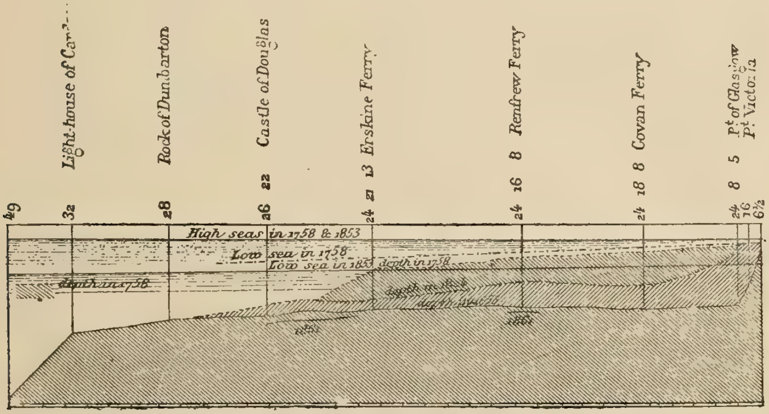
ALL the progress realised in the reclamation of the soil would have been impossible if nations had not been placed in mutual connection by means of frequent modes of communication: commodities are thus interchanged between various climates, ideas become a patrimony common to all, and the creative intelligence of workers has been enabled to develop and increase.

The earliest roads used by men for the purposes of travel and of conveying their produce were the natural routes afforded by the shores of the ocean, the deserts of sand and hard clay or rock, devoid of all vegetation, or by the level surface or gentle undulations of prairies and savannahs. Thanks to these ready-made ways of communication, nations separated by water, forests, and mountains have been enabled to make one another's acquaintance; but for all this, the mutual relations which they established remained very difficult to keep up. The sea-shores were intersected with quagmires and mouths of rivers, both dangerous to cross; the deserts and savannahs are the abode of famine, and the traveller who ventures into them unprovided with food is certain to perish. After the lapse of thousands of years and thousands of ages, these natural routes still continue as dangerous as they were when they were ventured upon for the first time: nothing but his skill and industry has enabled man to create for himself safer and more commodious roads.

The invention of rafts and boats suggested other modes of communication between peoples; they could now avail themselves of the winding courses of rivers —those "moving roads." This was an immense progress made in favour of intercourse between nations, for every river with its tributaries tended to connect together all the countries comprised in its basin. This amount of progress was, however, in its turn surpassed. In the civilized countries, where man is gradually moulding Nature to his will, these uncertain watercourses, with their long windings, their dangerous rapids, their sudden floods, and their prolonged droughts, were no longer adapted either for merchants or travellers, both classes having become more and more particular in regard to speed and regularity. The inland navigation diminished, except on the mouths of rivers, which were also estuaries of the sea, and had been converted by the skill of the engineer into regular canals having a considerable normal depth. This was the case as regards the Clyde, the bed of which a century ago was only three to six feet below the surface of the water; it is

now dug out to a depth of 24 feet, so that large ships can easily ascend the river up to the quays of Glasgow. Inland, the natural waterways were abandoned for artificial canals, the direction and depth of which man could regulate at his will; they were also to a great extent abandoned for carriage-roads constructed across the country in every direction and forming an immense network, and for railways, on which steam enabled a still greater speed to be obtained. Engineers have already made a demand for the suppression of our European rivers, such as the Loire, the Rhone, and the Rhine, as mediums of communication, and for the utilization of their waters for the irrigation of the land. "Rivers are roads for savages only," says M. Love, "and the only routes for transport recognized by civilized man are those which he has himself created from beginning to end." And in fact, looking at the millions of money which have been expended on the Loire since the commencement of the century in repairing dikes, embankments, and houses, in flotillas of boats, and in reclaiming cultivated land, would not this cost have amply sufficed for the construction of a double line of railway along the whole extent of the valley, and for establishing a complete system of irrigation, which

Fig. 201.– The Progressive Depths of the Clyde.



would have changed into a vast garden all those tracts of land which are now constantly threatened with some calamity by the rising waters?

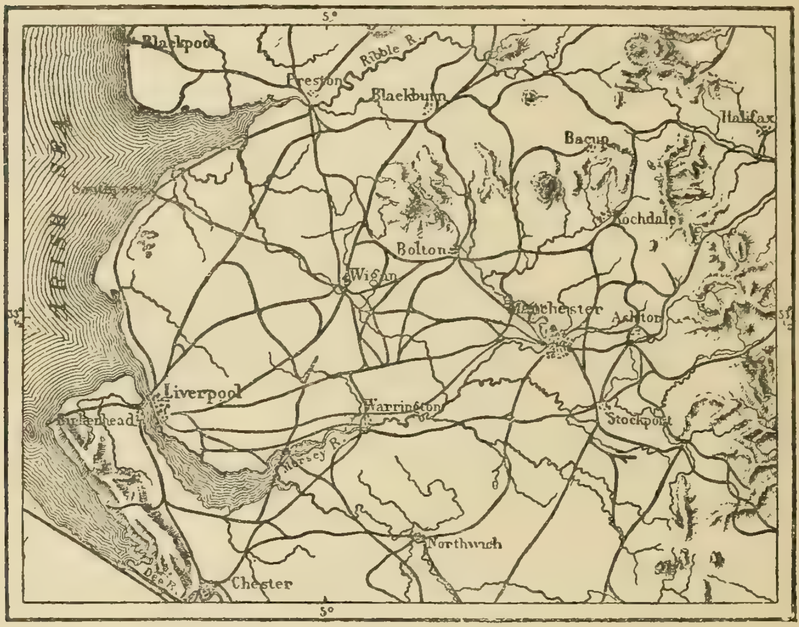
Among all the great inventions of modern times, that of railways has indisputably contributed the most to give an impulse to travelling, to the diffusion of ideas, and to the general distribution of the riches of the earth. The services which railways have already rendered to mankind are incalculable; but nevertheless, the power of routine, the requirements of the public treasury, the impediments offered by custom-houses, the greedy system of monopoly and gain practised by the various companies, the absence of any large comprehensive views among the constructors of the network of lines, and the troubles and disasters of war, have singularly retarded the impulse which might have been given by the iron roads to the activity of nations. Railways are, however, as yet but very few in number in comparison with the area of the ground which they traverse; their total length was over 210,000 miles in 1884, that is, about one mile only for a surface of 150 square miles. Few of the great lines, which ought to cross various parts of the world from one sea to another, are as yet completed. The longest, which commences at Cadiz, and extends for a length of 4200 miles, passing through Madrid,

Paris, Berlin, St. Petersburg, and Moscow, does not extend beyond Nijni-Novogorod, in the plains of Russia; twice this length remains to be accomplished before the rails reach the shores of the Sea of Okhotsk. The line crossing this, that which extends from the Straits of Dover towards Constantinople, has been arrested in its progress, for more than 20 years, by the course of the Danube. With regard to the New World, it possesses since 1869 a railway 3730 miles in length, which crosses the continent from the Atlantic to the Pacific, from Portland and New York to San Francisco, and which has already become one of the chief commercial arteries on the globe. To this was added, in 1886, a still longer line, crossing the whole of British North America, from Nova Scotia on the Atlantic to Vancouvers Island on the Pacific seaboard.

The districts where the railway system is anything like complete are at present very few in number. The richest district in this respect is that of Lancashire, in

202.—Railways of Lancashire.

Scale 1 : 1,000,000.



which the first important railway—that from Manchester to Liverpool—was opened in the year 1830. On this classic soil of the textile industries, there may be reckoned at least one mile of railway for every four square miles of area. The great facility of communication has also resulted in attracting to these districts a population truly enormous, when compared with the small area which they occupy. In the same way London, to which railways converge from all the points of the compass, increases its inhabitants at the rate of 60,000 a year, and in its onward march continually embraces within its boundary the towns, the villages, and the hamlets of the environs. London alone already contains nearly one-fifth of the population of England and Wales. Certain thickly populated regions in Belgium, Rhenish Prussia, and Massachusetts are also crossed by railways in every direction; but everywhere else, except in the vicinity of capital cities, the network of lines is still very far from being completed. Some continents are almost entirely without

Ocean

PASSAGES OF A

F A MAURIENNE

PL. XXVII.

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this mode of rapid communication. South America, which is twice the size of Europe, does not possess more than 1800 miles of railway. If we except Hindustan, the only railway in the continent of Asia is that from Smyrna to Ephesus; Africa also is devoid of railways, except in the extreme north and south, that is, in the two colonies of Algeria and the Cape of Good Hope, and in the Nile basin, which, as far as commerce is concerned, is only a colony of Europe.

During the last fifty years, £3,600,000,000 have been expended in various countries in the construction of railways; and even this large amount is nothing but a small sum compared with that which it will be necessary to expend in order to continue and complete the work which has been undertaken. No one can fail to see that these expenses are very different from those which are employed by man in the art of destroying one another, and that their tendency is to create fresh wealth and to bring nations into friendly relationship. The fraction of national savings which is able to escape the rapacity of taxation and the squanderings of luxury and debauchery, although still, alas! too small an amount, will serve however to bring to a happy completion those enormous works of which our ancestors never dreamed; and we must not think of styling even these works as "wonders of the world," because some day still greater works will be attempted. The Pyrenees, the Cevennes, the Vosges, the Jura, the mountains of Bohemia, and the Apennines are already crossed by railroads, and at Soemmering and the Brenner, the Alps have submitted to the hand of the engineer. In America the locomotive climbs the Californian Sierra-Nevada to a height of 7100 feet, and farther east it crosses the Evans Pass in the Rocky Mountains at an altitude of 8400 feet. In surmounting the Sangre de Cristo range, another railway in the United States attains an elevation of 9470 feet at the Volta Pass in Colorado. In South America also the two lines between Lima and Oroya, and between Arequipa and Puno, cross the Peruvian Andes at a height of over 13,300 feet. In the time of Hannibal and the Romans, and down to the earlier years of the present century, no one could travel from La Maurienne to Italy, except by the pathways of the two Mounts Cenis, or through formidable passes intersected by precipices and almost always obstructed by glaciers. Since 1840, one route enabled the travellers of the two nations to communicate with one another at all seasons; but the pressure of the two commercial currents seeking to be connected across the rampart of the Alps soon became so strong that it was found necessary to improvise a railway of a special construction, whilst waiting for the great international road which has since overcome the obstacle of the Alps between Paris and Turin. A tunnel 13,360 yards long now pierces the Frejus Mountains between Modane on the French and Bardonnecchia on the Italian side of Mount Cenis, and another 16,550 yards long has recently been opened under the St. Gothard. The Simplon, and probably also Mounts Genèvre and Tenda, will one day yield in their turn.

The engineers who can pierce through mountains have no longer any fear of suspending their iron ways above the widest rivers or even over arms of the sea. In Canada, a viaduct nearly two miles long crosses the St. Lawrence; not far from the falls of Niagara, a bridge carrying four lines of rails crosses the abyss into which the water dashes down. In England, the Straits of Anglesea, the estuaries of the Mersey, Saltash, Forth, Tay, and many others, are, or soon will be, crossed by magnificent tubular and suspension bridges; and sooner or later the two shores of the Bosphorus and of the Strait of Messina will be connected by bridges, over which railway trains will rush. Lastly, for some years past engineers have been emulating one another in proposing to do away with the gap, presented by the

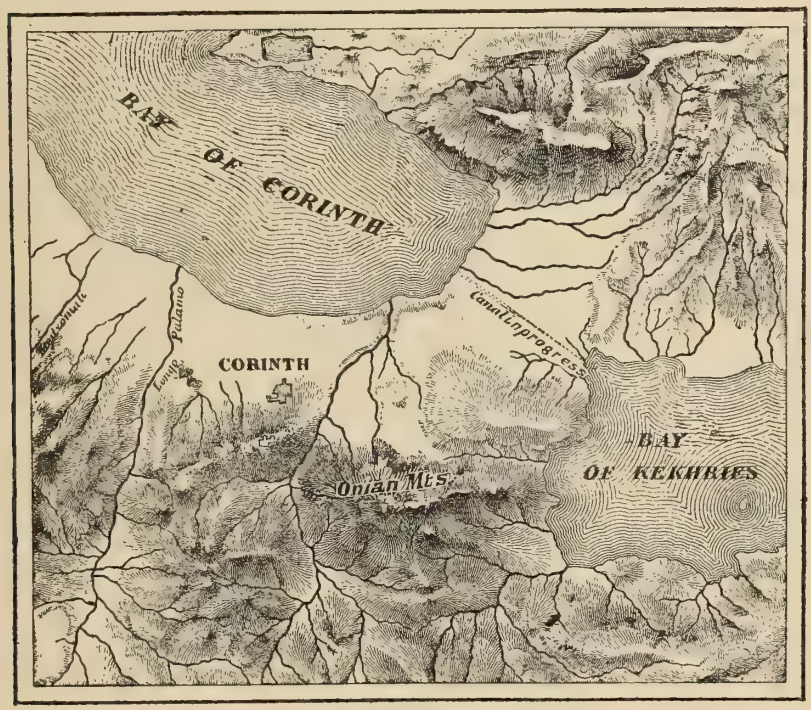
Straits of Dover, between the continental network of railways and those of Great Britain, either by a tunnel under the bed of the sea or by constructing a bridge 22 miles long between the two cliffs. This is far from being a mere chimerical dream: the money spent in the terrible contests of Solferino or Sadowa would have amply sufficed for the execution of this work. In a few years skill and perseverance will probably have reconstructed the isthmus between England and the mainland, which the waves took thousands of centuries to destroy.

In the same way as straits are no longer allowed to arrest the progress of the locomotive, so isthmuses have to open out for navigation and to complete the work of the remoulding of the earth. The ancients formerly tried their hands at these great works, but their attempts never attained any definite result. Thus the Greeks, and after them the Romans in the time of Nero, commenced at various times to cut a canal between the two bays, one in the Ionian Sea and the other in the Archipelago, which are separated by the isthmus of Corinth. At the spot chosen, the land to be cut through was not more than four miles wide, and rose from the two coasts in a gentle slope to a level of 190 feet in height. If we take into account the small dimensions required for a canal intended to carry only Greek and Roman galleys, the labour of excavation would not, at the present day, seem anything extraordinary; but the difficulties appeared insurmountable to the engineers of old, and the vessels which desired to pass from one gulf to the other were compelled to make a great circuit round the promontories and isles of the Peloponnesus, exposed to all the dangers of the main sea. However, the work has recently been again resumed, and a ship-canal some 25 feet deep will soon flow between the gulfs of Corinth and Kekhries.

The navigable canal, commenced by Pharaoh Necho twenty-five centuries ago, between the Nile and the Gulf of Suez, was a task more easy to finish successfully than cutting through the isthmus of Corinth; for the only point in question was to make, across the lowlands of the desert, a supply channel, bringing down the fresh water of the river to the Red Sea. One of the Ptolemies completed this work, which for a long time had been abandoned; after some centuries of interruption, Caliph Omar caused it to be repaired thoroughly by his lieutenant Amrou, and for some years it facilitated the exchange of commodities between the Delta of the Nile and the towns of Arabia. At the present day, this water-road, having been re-dug without any difficulty by the French engineers, not only serves for the transport of merchandise and commodities between the fluvial basin and the Red Sea, but also supplies fresh water to the town of Suez, the inhabitants of which had been in danger of dying of thirst, on account of the deficiency of springs and rain-water; it also tends to fertilize the land which lies on either bank, which were formerly devoid of all vegetation. But this canal, although it is more useful and certainly more durable than our ancestors could ever have made it, is nothing more than a mere detail of the magnificent work commenced in 1864. The great canal, which had been in the course of construction since that date, and was terminated on the 1st of October, 1869, is a real arm of the sea 99 miles long, re-establishing the communication which formerly existed between the Mediterranean and the Indian Ocean, as proved by the geological features of the district. The canal is deep enough to receive ships drawing a great depth of water, and wide enough for two lines of vessels to pass one another without difficulty; in addition it is provided with vast inland ports, in which a whole fleet can be laid up, and with two magnificent ports at each end, one of which, that of Port Said, is already the safest and most commodious in the whole of the Mediterranean, next to that of

Marseilles. The mass of earth which it was found necessary to move in order to open out the route for ships was not less than 95,000,000 cubic yards, so that if the rubbish were thrown up in a heap, it would form a pyramid 31,470 feet in circumference at the base, with a height of 1100 feet. In consequence of the attraction which such an immense field of labour could not fail to exercise over the population of Egypt and of Europe generally, the desert has become inhabited and dotted over with gardens and oases; two important towns, Port Said and Ismailia, have risen out of the sand; nearly 40,000 inhabitants have established their dwellings in these plains, into which the traveller could not formerly make his way without trembling. And what will these earliest groups of colonists be in comparison with the multitudes which will flock from every quarter when Port Said and Suez have become new Constantinoples, and receive the whole or even a part of the enormous traffic of nine

Fig. 203.—The Isthmus of Corinth.



millions of tons which, until the opening of the canal, went every year round the Cape of Good Hope, thus lengthening the nominal extent of their passage 7400 miles every voyage! Certainly, it does not seem out of the way to expend £20,000,000 on such an undertaking as this, looking at the fact that the merchants of Amsterdam, in order to spare their ships the short circuitous route through the Zuyder Zee and the passage of the Texel, have not hesitated to construct one canal, 50 miles in length, across the peninsula of Holland, and also another only 15 miles long, which have cost them not less than £2,400,000. The latter canal cuts through the peninsula at its commencement, and crosses the former lagunes and marshes of the Ij, which have already been changed into magnificent polders.

The opening of the Suez Canal was naturally followed by the adoption of a scheme to pierce one of the isthmuses of Central America. So early as the year

1528, Cortez, having ascertained that no straits existed between the Gulf of Mexico and the Southern Ocean, applied himself to the means of creating one, by cutting a navigable canal through the isthmus of Tehuantepec. Since the time when the former American colonies became free countries, and were liberated from the commercial trammels imposed as a right by a few houses in Seville and Cadiz, projects for cutting through the isthmuses have presented themselves in large numbers, some laid down at hazard on merely fancy maps, and others studied with all the care that a knowledge of the country could suggest, and brought forward by men highly esteemed in science. The portion of Central America which engineers have vied with one another in crossing with their various plans for canals, either with or without locks, comprehends without exception all the narrow parts of the extensive district which joins Mexico and South America. The isthmus of Tehuantepec, and that of Honduras, the valley of San Juan, and the narrow belt of country which separates the waters of the Pacific from those of the two lakes of Nicaragua and Managua, the isthmus of Chiriqui, the Rio Chagres and Panama, and Darien, the narrow stalk which connects the northern continent with the enormous mass of South America, have been in their turn extolled as the spots where the great commercial port of the world must necessarily be opened out. According to M. Jules Flachat, the sum that would be required for the easiest of these undertakings, that of Nicaragua, would be about £12,800,000, whilst the most costly plan, that which would take the course of the Atrato and the Truando, would involve an outlay of £30,000,000. But the scheme finally adopted at the Paris Convention of May 15th, 1879, is that of Messrs. Wyse and A. Reclus, which will cut the isthmus along the line of railway already constructed between the two ports of Colon (Aspinwall) and Panama. The canal now in progress will be 44 miles long, and will pierce the Cordilleras by a tunnel 2000 yards long and 110 feet above the water-level. Its cost is variously estimated at from £20,000,000 to £34,000,000, a small sum compared with the vast treasures yearly expended in the purchase of war materials, but considered a large amount for a work of universal interest, the result of which will be to bring the continents closer together, and hasten the day of the great reconciliation of nations.

ISTHMUS OF SUEZ

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CHAPTER LXXVI.

THE INDUSTRIAL POWER OF MAN.—THE ELECTRIC TELEGRAPH.—POSSESSION TAKEN OF THE SEA.—CULTIVATION OF OYSTERS.

IT has been calculated by statisticians that, in the year 1860, all the machines working in Great Britain for the benefit of manufactures generally represented an amount of power put in force equivalent to that of 1,200,000,000 of strong men: this considerably exceeds the collective force of the whole of mankind, for, among the 1,600,000,000 of human beings existing, three-quarters of them are either too weak, too young, or too old, to be adapted for any continuous labour. And yet this enormous total of manufacturing power in England is increasing every year at a rate equivalent to that of several millions of "arms'-power;" in France, in Germany, in Italy, in the United States, in Hindustan, China, Japan, and Egypt—in fact, in all the countries where civilization has introduced its machinery—the increase of the motive powers applied to labour in general is taking place in a similar or still more rapid proportion. Thanks to winds, water-power, steam, and other natural agents which man has enlisted to do his work for him, manufacturing skill every year achieves a task of increasing grandeur, and is incessantly contributing more actively to modify the aspect of our globe.

But what are the wonders of to-day compared with those which science will some day give us the means of accomplishing? When we shall be enabled to lay hold of and to fetter so as to make it work for us at our will, the power exercised in a limited space by the sustained blast of one of the hurricanes of the West Indies; when we are enabled to employ the active force developed by the waves which break during a stormy winter on the dikes of Cherbourg, or even the flow of the tide which covers every month the shores of the Bay of Fundy; when we know how to deprive volcanoes of the terrors which they inspire, and to conciliate for our use the formidable power of the lava and the compressed gases which are at work in their abysses—what works will be so colossal that labour and boldness will recoil from them? We may fearlessly assert, that all that man has hitherto done is but a trifle in comparison with what he will be able to effect in the future, when the forces at his disposal, instead of neutralizing one another, will be able to work in concert. If our rude ancestors, who inhabited caves during the stone-age, were to return among us, they would without doubt be too ignorant to understand, or even to wonder at, the immense progress made since the ages of barbarism. And are we ourselves at the present day sufficiently advanced even to form an idea as to what the surface of the globe will be when man shall have, so to speak,

reconstructed it, aided by the means of increasing power which will be furnished to him by a thorough knowledge of nature and her phenomena?

Among the material achievements of modern science, that which gives us the highest hope in respect to the future progress of mankind is the electric telegraph. By this invention man ceases to be connected merely with that part of the globe on which he treads so lightly; his liberty is set free from the obstacles imposed by time and space, and he becomes, as it were, personally present at all the points of space which the conducting wire brings into relation with his thoughts. To the power of his machinery, which might be compared to *muscular* force, he adds the *nervous* forces afforded by fibres stretching in every direction; news, transmitted from cell to cell, reaches the brain of man from all the ends of the earth, and his expressed wishes are flashed across continents so as to be transformed into actions on the other side of the globe.

The construction of electric telegraphs did not commence until about ten years after the completion of the earliest railways; but owing to the comparative simplicity of the works requisite for the establishment of electric wires, the total length of telegraph lines already much exceeds that of the iron roads. For an expense of about £40,000,000 we have been able to set up more than 1,500,000 miles of wires, a length which would reach nearly 650,000,000 miles, if we were to reckon all the double and multiple wires of importance. The new wires unrolled every year would be sufficient completely to girdle the whole circumference of the planet; it is the far-reaching stretch of the human will which is thus extended so far over the domain which it has made its own by its skill and energy.

Not only on the surface of the mainland, but also in the depths of the sea, does the electric fluid transmit the thoughts of man all round the globe. By about fifteen wires which rest on the bed of the Channel or of the North Sea, Great Britain is connected with the coasts of France, Belgium, and Holland; Sweden and Norway are directly joined with Germany by wires across the Baltic; Sicily and Sardinia have, in spite of the Mediterranean, become portions of the Italian mainland. We can still recollect with what emotion we greeted the first interchange of thought flashed from one side of the Atlantic to the other, passing under the immense body of water 2200 fathoms deep and as broad as an eighth part of the circumference of the globe. These first words which the Old World thus sent to the New were words of peace and good-will; it was understood by all that the great fraternity of man had then asserted its existence in a most solemn manner; in spite of all the obstacles nature could offer, in spite of continents, seas, and space, widely distant nations were beginning to be sensible of one common soul. After transmitting these words of peace and scrawling some indistinct syllables, the Transatlantic cable, as if exhausted by its first effort, and, as it were, ceasing to live, refused to respond to the learned electricians who were soliciting it on both shores of the ocean; silence had resumed its empire across the broad tract of water. But the persevering Anglo-Saxons did not succumb to the blow of this defeat: they again manufactured thousands of miles of fresh wire, and commissioned their engineers and their most skilful mariners to lay it down in the bed of the ocean. Then, with an anxiety as great as that experienced on the eve of a decisive battle, they witnessed the departure of their finest ship, unrolling as it went the cable which was to unite them to their American brethren. Fresh misfortunes followed: the wire broke in the open sea. No matter; they laid down a third, and the mighty "Great Eastern" made her voyage across the Atlantic without ceasing for one instant to keep up a communication with the coast of

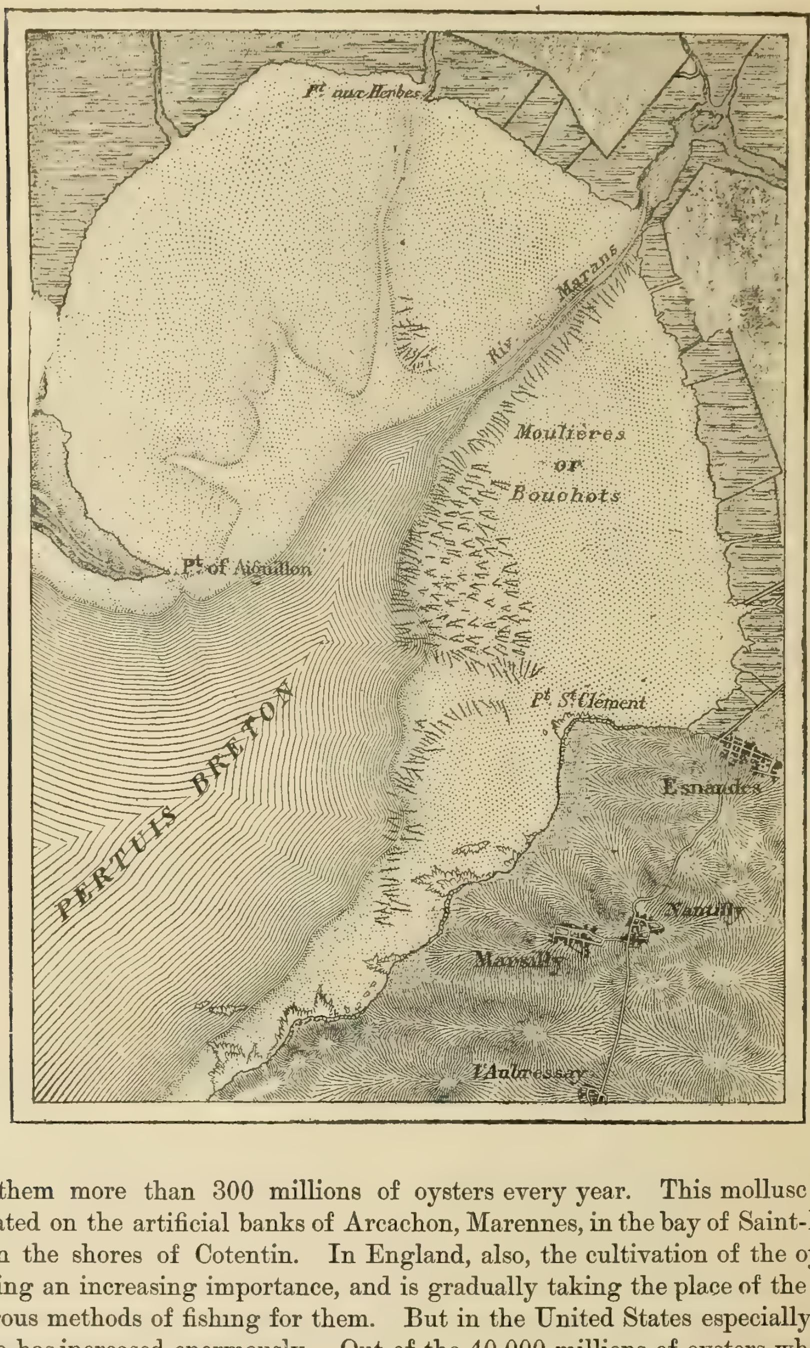
Ireland, just as if she had left in her wake a long electric furrow. At the present time eleven electric telegraphs connect the two opposite continents, including those now completed between Brest and New York, Havre and Portland, Lisbon and Pernambuco, and Mr. John Goulds' Cable laid down in 1885. Lines, however, of no very great length, especially that from France to Algeria, by way of the Balearic Islands, have not been successfully established in a permanent way, the cables having often been broken; the cables also in the Eastern Mediterranean, the Red Sea, and the Indian Ocean have been frequently injured. A total length of 90,000 miles of telegraphic wires distributed amongst 600 separate cables has been laid down in the bed of the sea between various parts of the world, its islands and peninsulas; but there does not at present exist any one continuous line which belts round the whole circumference of the planet, passing across the continental masses and the depths of the ocean. The longest line, that between California and New Zealand, passing through New York, London, Vienna, Constantinople, Bagdad, Calcutta, Singapore, and Sydney, is not less than 20,000 miles in length.

The great undertakings which have been already accomplished on the coasts and in the depths of the ocean justify us in asserting that man has taken possession of the seas, which are no longer "an insuperable abyss," and most of which have already been explored. Nearly 200,000 ships traverse the waves between the coasts of the various continents and islands; more than a million of sailors have made their homes on the dreaded billows, and half their lives are spent in ships which float on the waves and are beaten by the tempest. Sea voyages become more and more frequent, and the number of travellers who cross every year from one side of the Atlantic to the other must now be reckoned by hundreds of thousands; they equal the number of passengers who travel from Great Britain to the Continent over the narrow waters of the North Sea, the Straits of Dover, and the Channel. Not only are the natural ports afforded by the bays and river-mouths improved by hydraulic works of every kind, but new harbours are opened for ships on the most dangerous coasts. Thus the dreaded shoals of Holyhead, Kingston, and Howth, and the rocky islets of Cherbourg and Plymouth, have been utilised as foundations for jetties and embankments, inclosing large areas of water, where great ships may find a safe refuge. In other places, as at the mouth of the Danube, the two banks of the river have been pushed out to a considerable distance into the sea, so as to reach deep water. At Portland, the summit of a hill has been thrown over into the sea so as to form an immense breakwater, inclosing a whole bay where fleets might safely manœuvre. The idea has even been started of constructing harbours in the open sea. M. Thomé de Gamond has proposed to utilize the Varnes bank, in the middle of the Pas-de-Calais, for establishing a great harbour of refuge on the track traversed every year by more than a hundred thousand vessels.

Another attempt at taking possession of the sea is that which has been made by the "farmer" of its waters. This attempt is not limited, like that of the hunter on the dry land or of the fisherman on rivers and in the ocean, to merely catching animals in order to make food of them; but, rising a degree higher in civilization, the "oyster-farmer" has learnt to imitate pastoral nations, and instead of like a savage destroying living beings without paying any attention to the maintenance of the species, he makes it his business, on the contrary, to increase the number of its individuals by rearing them, and takes care of them in order to ensure his future subsistence. Thus the "oyster-farmers" cover their submarine fields with faggots, stones, and tiles, to which the spat sticks, that is, the innumerable multitude of small organisms which will ultimately develop into oysters. When the molluscs,

after having escaped the thousand causes of destruction by which they are surrounded, have attained some little size in the beds, they are fished up and removed to fatten in reservoirs where they reach their full growth. The fishermen of the Ile de Ré, who commenced the cultivation of oysters scarcely twenty years ago, have already established beds which extend over an area of 15,500 acres, and they obtain

Fig. 204.—Mussel-Beds of Esnandes.



from them more than 300 millions of oysters every year. This mollusc is also cultivated on the artificial banks of Arcachon, Marennes, in the bay of Saint-Brieuc, and on the shores of Cotentin. In England, also, the cultivation of the oyster is assuming an increasing importance, and is gradually taking the place of the former barbarous methods of fishing for them. But in the United States especially oyster culture has increased enormously. Out of the 40,000 millions of oysters which are

eaten every year in America and Western Europe, the share in the consumption taken by the United States is nearly 35,000 millions. The quantities of mussels which the fishermen dredge up on the coasts and make articles of commerce are also most considerable. In the roadstead of Aiguillon alone, where the culture of this mollusc has been practised ever since the thirteenth century, more than 500 fishing-hurdles or ranges of palisades may be reckoned, on which the mussels hang in immense clusters; the mussel-fishers collect them by millions every year off one palisade alone.

Recently some enterprising Americans have invested large sums in breeding and grazing numerous schools of cetaceans. The *otaria ursina*, which, like the sea-cow, was threatening to disappear, is now herded in vast numbers on the islands of Behring, Pribilov, and Copper, between Kamtchatka and Alaska. These animals, whose extremely soft fur is highly prized, are carefully tended, and allowed freely to roam within certain prescribed limits. The speculation has already yielded handsome profits, besides preserving this valuable species from all danger of extinction.

The cultivation of marine plants has not yet been undertaken by man. All he does in this way is to collect the seaweeds on the beach, mixed with fragments of shell-fish thrown up by the waves, and to utilize them for manuring his fields. This employment of seaweed is however entirely local in its character, and is inconsiderable in extent. If only agriculturists desire it, they can find for all the arable land in the world an inexhaustible quantity of manure; to do this all that would be necessary would be to send fleets to gather cargoes of sea-wrack in the interminable prairies of sargasso in the Atlantic and Pacific Oceans.

CHAPTER LXXVII.

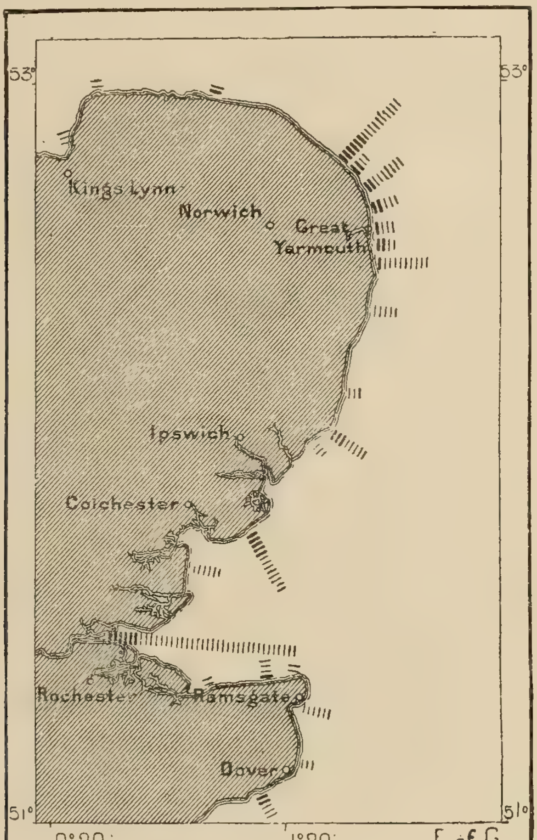
COMPARATIVE HARMLESSNESS OF HURRICANES.—PREVISION OF WEATHER.—MODIFICATION OF CLIMATES EFFECTED BY THE LABOUR OF MAN.

ANOTHER circumstance which singularly contributes to hasten the complete conquest of the seas, is the fact that winds and even terrible hurricanes have lost some of their power over man. Thanks to the previsions which science has enabled our mariners to exercise, these meteoric phenomena become less and less terrific; and their beneficent action in blending different bodies of air is no longer accompanied, as it once was, by so large a number of local disasters. Guided by the appearance of the sky and of the sea as well as by the oscillations of the barometer, the captain of a ship sees beyond the horizon the tempest which is approaching, and fearlessly takes proper measures in order to avoid in good time the formidable cyclonic storm which is about to burst upon the sea. As far as regards a well-commanded steam-ship, "a hurricane is no longer a possible event;" the cyclone is nothing more than an ordinary whirlwind all round which a ship may sail without danger, keeping away from it if there is any fear of becoming entangled in the vortex, and on the contrary approaching it, if the direction of the tempest may be made favourable to its course. The hurricane, which was the terror of navigators in former times, may thus become in our days a powerful auxiliary. In the vicinity of the coast, the danger of course remains very great, because the ship has not a free space before it; therefore when a hurricane is anticipated, mariners are compelled to put out as soon as possible into the open sea.

Coasts, along which the navigators of the olden time used servilely to creep, dreading to face the terrible Neptune, are now avoided by sailors, for it is on the coasts, and principally on the low-lying beaches, that nearly all the shipwrecks take place. The descriptive charts which are drawn up by the salvage societies to show the proportion of calamities occurring on the various points of the coasts of Great Britain and France, bear witness to the formidable nature of these dangers; out of 100 vessels, two on the average have to suffer disaster in each year. The seas which are tranquil and deep enough to enable vessels to sail at all times without fear in close proximity to the coast, are less numerous; the shores of the Mediterranean are no less sprinkled with wreckage than those of the ocean, and some of these spots, especially that portion of the curve which extends between Cette and Marseilles, are particularly dreaded. In order to diminish the number of shipwrecks, attempts have very rightly been made to improve the ports, to open harbours of refuge, to light up dangerous coasts with beacons visible at a great

distance out at sea, to point out shoals by means of landmarks and buoys, and to communicate with mariners by means of the telegraphy of semaphores; and above all, a precise knowledge of the movements of the atmosphere, enabling one to form an increasingly clear prevision of the phenomena of the weather, are the means by which disasters at sea may be best prevented. Navigation, especially steam navigation, which enjoys the immense privilege of speed, will have but very few dangers to fear when mariners understand the art of manœuvring in order to avoid

Fig. 205.—Shipwrecks on the South-east Coasts of England.



Total Wrecks. Partial Wrecks.

tempests, and every vessel has become a floating observatory, as suggested by Maury, the illustrious American sailor.

At every period of history men have made it their business to endeavour to foretell the weather. Owing to the numerous advantages which are offered us by civilization, the practical utility of knowing beforehand any approaching meteorological changes has become less urgent, because in the present day we can to some extent shelter ourselves from the influence of these variations by our clothing, our dwellings, and our food. There are even some people who, by means of an altogether artificial mode of life, have arrived at the point of being unacquainted with the greater part of the meteoric agencies of the air. This was not the case with the nations of antiquity. Living in the open air or in ill-closed huts, seeking

their livelihood in hunting, fishing, agriculture, or in rearing cattle, they were compelled incessantly to search the horizon in order to discover the earliest antecedent signs of wind, storm, and rain. By a constant examination of the heavens, the most skilful observers were enabled to discover more or less accurately a considerable number of facts which placed them in a position to foretell the weather; especially in countries where the phenomena of the atmosphere took place with some degree of regularity, as in Egypt and the Indies, those who were called "wise men," on account of their knowledge of times and seasons, learnt to make fortunate forecastings as to the approaching changes of temperature, which were not indicated to the common herd by any outward signs. Having been converted into proverbs which were repeated from mouth to mouth, a great portion of these predictions have come down to our time, and in the different localities where they were originally uttered one may now judge of the amount of truth which they afford. Many little-known facts have been verified for thousands of years past by these popular sayings, and a great service would be rendered to science by collecting these scattered proverbs uttered in the infancy of nations.

Nevertheless, in their desire to know beforehand the various changes of temperature, experience is not the only thing to which men have appealed; they have sought to discover, in the movements of the stars, the future not only of the seasons but of their own personal destinies. They claimed to attain to a prescience of the variations of the weather by the apparitions and conjunctions of distant planets, and not by the phenomena of the atmosphere itself. These astrological chimeras, which moreover suggested to ambitious soothsayers the means of obtaining an ascendancy over the minds of others by the prestige of the supernatural, have not as yet entirely disappeared from science, and are reproduced from time to time under a borrowed garb more or less scientific. Without feeling ourselves compelled either to assert or to deny the influence exercised by the heavenly bodies on the phenomena of the terrestrial atmosphere, it is certain that, in order to attain ultimately the great end of foretelling the weather, it is necessary to proceed methodically by observations of ever-increasing accuracy and completeness, made at all the various points of the globe. By classing all the special facts, and by discussing them so as to give to each its just value, we shall gradually discover the general laws which bear upon them, and then day by day draw back the curtain which is spread over the field of our sight.

Although the resources of civilization have rendered us more independent of the variations in the atmosphere than our ancestors were, nevertheless the interests which are constantly placed in peril by unforeseen modifications of the temperature are immense, especially as regards agriculturists and sailors; added to this, the inquirers into this subject have a special incentive to urge them on in their studies, in the powerful attraction which is presented to them by the study of the laws of nature. It is pleasant to be able to recognise order and rhythm in what at first seems to be nothing but the caprice of the elements, and to trace beforehand in the heavens the course taken by those invisible forces, the incessant conflict of which produces all the variations of weather. Such is the ambition which, at the present time, may reasonably be entertained. Not very long ago Arago expressed a doubt whether man could be thus able to foresee the alterations of temperature and of meteoric agencies; but at the present day nearly all savants, emboldened by the grand discoveries made during the last few years, are on the contrary full of confidence, and look forward to becoming, at an early future, masters of all the secrets of the weather. In England, Admiral Fitzroy; in Holland, MM. Buys-

Ballot and Andrau; in France, M. Marie-Davy and other meteorologists, have been able, owing to an attentive observation of the signs of the atmosphere and a comparative study of meteorological phenomena, to make an attempt to predict the weather two days beforehand; and more often than not their prognostications, placarded in all the ports on the sea-coast, have been found to be justified. M. Bulard, of the Observatory of Algiers, goes still farther; he announces changes of temperature weeks and even months before they take place. Moreover, the comparison of the events with the predictions cannot leave any doubt in the mind; following the courses taken in space by the meteoric agents, is the plan pursued by the observer in order to be enabled to point out beforehand the points where, and the time when, aërial currents will meet, where and when clouds will form, rain be condensed and the tempest break. When, in their daily comparisons, meteorologists will be able to make a free use, not only of the whole network of European telegraphs, but also of all the wires upon the earth; when they will be cognizant of the various daily phenomena observed at the American stations, and observatories, like advanced sentinels, are established at Bermuda, the Azores, St. Thomas, and Havannah, that is, at the various points from whence arise the winds, currents, and cyclones, which take their course obliquely across the Atlantic, then the prognostication of the weather will be placed on a sure basis. The savant will read beforehand the signs of the heavens, the mariner will know when he ought to remain in port, and the agriculturist will ascertain the best time for gathering in his crops.

There is, however, a triumph still greater than that of foreseeing the succession of meteorological phenomena, and that is the victory obtained by the modification of climates. In every age, man has been incessantly occupied in changing them by his labours of cultivation and by the amelioration of the soil; but this work has been carried out in an ignorant way, and too often the effect of man's activity has been to vitiate the air, or to render the alternations of heat and cold still more sudden and disagreeable. Thus towns, the temperature of which is always raised 3 or 4 degrees by the assemblage in them of a large number of people, are at the same time converted into centres of pestilence, whence poisonous gases find their way from the lungs of one to another. In the same way, in other countries, the wholesale cutting down of forests which has taken place has resulted in disturbing the harmony of nature. The mere fact alone of the pioneer clearing some virgin soil effects a change in the network of isothermal, isotheral, and isochimenal lines which pass over the country. In several districts of Sweden where the forests have been recently cut down, the springs at the present time commence, according to Absjiönsen, about fifteen days later than those of the last century. In the United States, the vast clearings which have been made on the slopes of the Alleghanies appear to have rendered the temperature more variable, and have caused autumn to encroach upon winter, and winter upon spring. Generally speaking it may be stated that forests, which in this respect may be compared to the sea, diminish the natural differences of temperature between the various seasons, whilst their destruction exposes a country to all the extremes both of cold and of heat, and adds still greater violence to the atmospheric currents. If we are to put faith in certain authors, the *mistral* itself, the terrible wind which swoops down upon the Cévennes and brings desolation into Provence, has been a scourge of mankind and has blown in its full violence only since the disappearance of the forests on the adjacent mountains. In the same way marsh-fevers and other endemic diseases have often broken out in a district after the woods, or even mere sheltering screens of trees,

have fallen under the axe. As to the general flow of the surface waters and the climatic conditions which depend upon them, there is no room to doubt that the result of the clearing away of forests is a disturbance of the regularity of the above-named conditions. The rain, which, by the intersected branches of these trees, descends drop by drop and subsequently trickles slowly through the dead leaves and the network of roots, when the forests are destroyed flows down fast upon the ground and forms temporary rivulets; instead of descending by subterranean sources to the lower strata and springing up again in fertilizing springs, it runs off rapidly on the surface of the ground and is lost in the streams and rivers. Up-stream the ground is dried up, and down-stream the body of running water is so increased that floods are converted into inundations, devastating the whole country along the river-side; dreadful disasters are thus brought about, similar to those which were caused by the Loire and the Rhone in 1856.

But man is now able to take account of the influence which his agency has exercised upon climate, either by improving it or making it worse, and any mischief that he has done he is able to undo. He knows that by again planting woods he has the power of modifying the extremes of temperature and of equalizing the amount of rain; he knows that by developing a system of irrigation he is able to increase the fall of moisture, as has been proved by the observations made in Lombardy during the last century; lastly, he can make a district healthy by draining the marshes, by clearing the surface of the land from decaying matter, and by modifying the various kinds of cultivation. This was the case in Tuscany, where the valley of the Chiana, once almost uninhabitable, into which the swallow scarcely dared to venture, has been completely set free from the marsh-miasmas by the rectification of an irregular slope, covered with pools and lagoons. In the same way, the marshes of the district which was the ancient Etruria, have become much less dangerous to the health of the inhabitants since the Tuscan engineers filled up the low grounds on the sea-shore, and have taken care to prevent the mixture of salt and fresh water which took place at the mouth of the streams. The amelioration of the air to be breathed is the mode by which man will resolve the important question of acclimatization; for the only hot countries that are really unhealthy for colonists who are natives of a temperate zone, are the moist regions, the air of which is saturated with miasmas. Even now, in spite of wars and of interruptions (extending through centuries) of the works of improvement, almost the whole of Europe has been rendered healthy by the labour of its population, and at the present time the same work is being accomplished by the inhabitants of North America, the regions of La Plata, Algeria, the Cape of Good Hope, and India; the enormous work which still remains to be done in rendering healthy the whole surface of the planet becomes every day easier, for now men recognise the power of association, and the means by which they can do so are furnished by science.

CHAPTER LXXVIII.

INFLUENCE OF MAN ON THE FLORA AND FAUNA OF A COUNTRY.—ENCROACHMENT EFFECTED BY THE MORE COMMON SPECIES.—EXTENSION GIVEN BY AGRICULTURE TO CERTAIN CULTIVATED SPECIES.

THE first relation of man to the various animals which surrounded him must necessarily have been one of conflict and destruction. The great battle of life was inaugurated by massacre. To eat or be eaten—this was the alternative, not only for man but also for the great cave-bear, the Attic lion, the *Machairodus*, and many other carnivora of past ages. There is no doubt that the struggle may for a long time have been indecisive, and perhaps in many places man may have been vanquished; but, after the various chances and changes of the conflict, the terrible wild beasts were ultimately killed down to the very last individual. Man, being more subtle than these monsters, and more skilful in hiding himself and in surprising them, was also ingenious enough to avail himself of artificial weapons, clubs, pointed bones, and axes or maces of stone, and was the conqueror in the conflict, whole races having disappeared before him. To say nothing of those animals which were exterminated at some unknown epoch in prehistoric times, it is probable that the *Schelk* of Germany and the great elk of Ireland were destroyed by hunters less than ten centuries before the present era. In our own time, the buffalo, the lion, the rhinoceros, and the elephant are constantly giving way before the advance of man, and sooner or later they, too, will become extinct. In thickly populated countries all the wild animals are in their turn destroyed, and are replaced by beasts which we use either as slaves or companions, such as the ox, the dog, and the horse, or those animals which, like the pig, are nothing more than walking masses of butchers' meat.

There are several races of birds the extinction of which must doubtless be a reproach to man; among these we may mention the *Alca impennis* of the Faröe Isles, the *Dodo* of the Mauritius, the *Solitaire* of Réunion, the *Lory* of Rodriguez (*Psittacus rodericanus*), the *Æpiornis* of Madagascar, the twelve or fourteen species of *Moas* of New Zealand, the *Apteryx* and the *Palapteryx*. M. de Lungershausen also points out as being extinct or in the course of becoming extinct, seven curious species of birds in the Sandwich Islands, Tahiti, New Zealand, Norfolk Island, and the Samoan archipelago, which have been hunted to destruction by man, or by his companions the dog and the cat. The sea-cows of Steller (*Rhytina Stelleri*), the enormous cetaceæ weighing 22,000 lbs. which were discovered by the geologist of that name and his companions in 1744, and which frequented in great numbers the coasts of Behring's Straits, became completely extinct in the course of 27 years,

and since 1768 not one of them has been seen ; not even an entire skeleton is left. The whale, which recently enjoyed a short respite owing to the American war and the working of the petroleum springs, is now again most energetically pursued, and soon will not find any sea where it can take refuge ; the seals are every year slaughtered by hundreds of thousands ; the sharks themselves diminish in number along with the fish which formed their prey, the latter having become the spoil of the fisherman. The butchery year after year of the birds which feed upon insects has resulted in a formidable increase of the numerous tribes of ants, termites, locusts, caterpillars, &c., and in the same way the cetaceæ and fish which have disappeared are replaced by myriads of *medusæ* and *infusoria.*

With regard to this subject, Mr. Marsh expresses an opinion which at first sight cannot fail to surprise, but is none the less worthy of being taken into serious consideration. In his opinion, the very remarkable phenomena of the phosphorescence of sea-water has become more frequent in modern times, and more beautiful than it was two thousand years ago. Homer, who often speaks of the "thousand voices" of the Ægean Sea, makes no mention of its thousand glimmerings. In the same way, the poets who have represented Venus as springing from the foam of the sea and have peopled the "watery abodes" with so many nymphs and divinities, have not given us a description of the sheets of liquid gold on which, during the night, the bright shining goddesses were used to recline. The love of the Greek poets for broad day and the full light of the sun might tend to explain this strange silence ; but why is it that savants also have maintained such a sobriety of language in describing this very extraordinary appearance of the phenomenon of the phosphorescent glittering of sea-water ? Aristotle, who speaks but briefly of it, attributes this light to "the greasy and oily quality of the sea." Ælian, the compiler, mentions the gleam emitted by the seaweed on the shore ; and Pliny, the encyclopedist, tells us that the body of a species of medusa emits a certain brilliancy when it is rubbed against a piece of wood. This is a point to which science had reached before the observations made by Americus Vespuccio on the phophorescence of tropical seas. Since this epoch there is not probably a single traveller who has not remarked on the jets of light springing forth during the night-time round his ship, not only in the West Indian seas, but likewise in the Mediterranean, on the European coasts of the Atlantic, and near the icebergs of the Polar Ocean. If Mr. Marsh's ingenious hypothesis is true, those among us who walk along the shore or sail over the sea when the waves are, as it were, on fire, enjoy a spectacle much more splendid than ever was given to our forefathers to contemplate. This, however, would be but a poor compensation for the ravages which have been made by our fishermen.

The action of man has also caused a rupture in the harmony primitively existing in the flora of our globe. The colossal trees in our forests are becoming more and more rare, and when they fall they are not replaced. In the United States and in Canada, the noble trees which astonished our first colonists have for the most part been felled, and in more recent days, before the finest forests in the countries of Mariposa and Calatrava became national property, the Californian pioneers had cut down, in order to convert into planks, many gigantic sequoias which had attained a height of 380, 390, and even 400 feet. This is perhaps an irreparable loss, for nature requires hundreds and thousands of years before she can supply the sap necessary for these enormous trees, and mankind, too impatient for proper enjoyment of it, and too indifferent to the fate of future generations, does not as yet sufficiently feel the extent of its own duration, so as to induce it to take

thought for the careful preservation of the beauty of its forests. The extension of the agricultural domain, and the requirements of navigation and manufactures, also result in reducing the number of trees of an average size. At the present time they are diminishing in number at the rate of millions every year. Even the toy-manufactories, and the chemical match factories, to say nothing of the ship-building yards, require whole forests for their annual consumption. To make up for this, in all the countries of the world, herbaceous plants multiply, and are covering areas of increasing extent. One might almost fancy that man was jealous of nature, and sought to dwindle down all the products of the earth so that they should not surpass his own level. Even now, as the natural consequence of the struggle going on between the various vegetable species, those which are common to several countries tend to smother gradually the more feeble species which try to hold their ground in some more limited district. Added to this, man also contributes towards the destruction of the original flora by increasing the field of growth of the invading plants. His migrations enable him to reclaim fresh tracts of land, and he sows them with the seed of civilized countries; in his course of cultivation he assails the mountains, marshes, and savannahs, where the local species have taken refuge; by his pathways, his roads, and his canals, he spreads far and wide, on a soil perhaps ill-adapted for them, the plants which surround his dwellings and grow in his fields. Not only in more or less extensive portions of one and the same zone do the vegetable species which are parasites of man increase their field of growth, but, at the very extremities of the world, they keep on annexing newly colonized lands. Just as European plants encroach on the indigenous species, so do the imported animals, delighting in their new climate, drive victoriously before them the representatives of the former local fauna. The pig, again become wild, has taken possession of the forests of New Zealand. The rat which once frequented the two islands, has been pushed out by the brown rat escaped from English ships, and the conqueror in the strife has himself become extinct in his turn, before the European *mus* tribe. The New Zealand fly carefully avoids his European rival, who has come all round the world in order to drive him out from the huts of the islanders. As the Maoris sadly remark, "The white man's rat drives away our rat, his fly drives away our fly, his clover kills our ferns, and the white man will end by destroying the Maori." One can well understand the despairing cry uttered by Michelet in his book, *La Montagne*—"Commonplace ideas and things will prevail!"

Oh, no! The ideal of man is the ideal which will always prevail. As long as this ideal is nothing else but the mere reclamation of ground for cultivation, everything will be sacrificed to this point, the variety and originality of species, and all the beauty of vegetation. But when the desire of obtaining productive crops from the earth is supplemented by that of adorning it and of giving to it all the splendour which art adds to nature; when agriculture, at last delivered from that fear of poverty which now persecutes it, and in possession of that leisure without which it is nothing but a slave of hunger, will be enabled, like the amateur gardener, to busy itself in varying species and tastefully grouping them, and in developing elegant or magnificent forms of vegetation, no doubt it will succeed in materially modifying the vegetable world according to its desire, and in giving it, instead of its primitive originality, a new beauty which will respond to a sentiment of æsthetic taste.

Taking the point of view of the distribution of species, the principal result of agriculture has been to give a widespread extension to certain plants which are

used either for the food of man or for the requirements of his industrial skill. The rice-plant, wheat, maize, the vine, the cotton-plant, the coffee-plant, each now covers millions of acres. The various cereals, although much less in number when compared with the 500,000 species of other plants, extend over an area of soil which cannot be estimated at less than a fiftieth part of the surface of the earth ; in some regions, as in North America, fields of corn may be seen some thousands of acres in extent, undulating away to the farthest horizon like lakes agitated by the wind. The plants cultivated by man have so extensively exceeded the limits of their natural field of growth, that out of the 157 species more generally cultivated, there are 72 which have not yet been recognized in their wild state, and as to the identity of which botanists still experience some doubt. Until a quite recent date wheat was known only as an agricultural plant, and it was looked upon as a kind of miraculous source of wealth, when M. Balansa found it growing spontaneously on a mountain in Asia Minor.

Northern nations push on their cultivation of the ground to a point within the polar circle, and very near the extreme limit where forests are found to grow. On the coasts of Norway, barley, which is cultivated nearer to the pole than any other cereal, does not succeed with any degree of certainty in districts above 66 degrees of latitude ; but it may be seen here and there, in sheltered valleys, almost up to the northern extremity of the Scandinavian peninsula. The most northern locality in which the inhabitants have found courage enough to cultivate it in spite of the climate, is Elobaken, in 70 degrees of latitude. In Swedish Lapland the cultivation of barley stops short at a point 90 miles farther south ; and yet the annual crops are generally speaking only half ripe, and the farmers have to dry them in kilns ; at Enontekis, a satisfactory crop is not obtained oftener than once in every three years In other northern countries which are not, like Scandinavia, under the influence of the Gulf-stream, barley cannot be grown with much hope of success except in districts situated considerably to the south of the polar circle. But in every spot in the frigid zone where any groups of civilized inhabitants have established themselves, in Siberia, Labrador, and Greenland, these "outcasts" as it were of the human race, have by dint of labour extorted from the ground a few vegetables belonging to more temperate climes, such as cabbages, turnips, lettuces, and spinach, half-starved plants which would certainly refuse to live in the ice-bound soil, were it not for the indefatigable care of the gardener who sowed them. On the slopes of the Swiss mountains man has likewise carried cultivation far beyond its natural limits. In many valleys of the Alps fields of rye, barley, and oats are to be seen at an elevation of 5000, 5250, and in the Val Tomanche, even at a height of 6509 feet above the level of the sea, scarcely 2300 feet below the limit of perpetual snow. The highest village in La Maurienne, in Savoy, is no less than 5898 feet above the sea ; nevertheless, the inhabitants have given it the name of Bonneval, inspired by a kind of gratitude towards the land watered by the mountain stream Arc. On the slopes which face the southern sun, the villagers indefatigably cultivate both barley and rye ; but it must be confessed that the crops are extremely late in maturing. The sowing takes place in July on fields where the snow has been melted by spreading on them black earth or barley stubble, and often in the month of August or at the beginning of September in the next year, the fields are still green ; fourteen months are required to ripen the harvest. In consequence of a truly heroic conquest effected by man's industry, cultivations on the northern slope of the Valais Alps are pushed upwards to an elevation averaging 330 feet higher than on the southern slope, which is nevertheless exposed to the beneficent

influence of the sun. The fact is, that the northern population, having a smaller extent of good land at their disposal, exercise more assiduity in their labour than the southern farmers.

M. Rosenthal, of Breslau, has enumerated no less than 12,000 plants employed either as articles of food or for their curative virtues and their utility in manufactures; but the most frequently cultivated species—those which supply us with food, clothing, and all that is requisite for life, in the absence of which man would disappear from the earth—constitute but a very small portion of the earth's flora. Europe and Western Asia are perhaps the districts which have supplied to the human race the most valuable species of vegetables; even in the times of the Chaldeans and the Pelasgi, these portions of the ancient world had bestowed on agriculture more than half of the treasures which she possesses. The Indies and the Sunda Archipelago, so rich in their vegetation, are the habitats of about one-fourth of the plants used in agriculture and manufactures, and the remainder come to us almost entirely from South America, which, as regards the multitude of indigenous plants, and taking its area into consideration, is certainly the wealthiest continent of all. There is only one species of high importance among cultivated plants, the date-tree, which finds its origin in Northern Africa. With regard to Australia, New Zealand, and the United States, none of these countries have as yet supplied to mankind any one plant of essential utility either for food or agriculture, if we except the materials requisite for the building of houses and ships.

It is an evident fact that men, too much the slaves of routine in their course of cultivation, have as yet turned to account but a very small number of the plants which might be useful to them, and among those that are cultivated with the greatest care many are species of a poisonous nature, such as opium, the betel-root, and tobacco, that odious weed, the use of which weakens the body and stupefies the mind! To say nothing of the various species of trees which have not hitherto been worked for building purpose, how many American plants there are, neglected by or even unknown to botanists, which might be useful either for the food of man or for the cure of his maladies, either by means of their stems, their bark, their fruits, their flowers, their germs, or their roots! Not long back our agriculturists made a most important acquisition in the virgin forests of Bolivia and Peru: they have taken possession of the Peruvian bark tree with a view of converting it into a *cultivated* plant. The natives, too eager to avail themselves of its virtues, know of no better plan than that of cutting down the tree and peeling off its bark; they traverse the forests in search of the *cinchonas*, and when they have found them, the axe is at once laid to them, and in the course of a few hours these trees, which might have supplied numerous crops of bark throughout a whole century, lay despoiled upon the ground. Fortunately, Clements Markham, the traveller, was successful in taking up a few young plants, and at the present time we have the *cinchona* growing in cultivated forests in Ceylon, the Island of Java, and on the mountain-slopes of the Himalayas and the Nilgherry Hills.

CHAPTER LXXIX.

INFLUENCE OF MAN ON THE BEAUTY OF THE EARTH.—DISFIGUREMENT AND EMBELLISHMENT OF THE LAND.—THE DIVERSE ACTION OF DIFFERENT NATIONS.—THE APPRECIATION OF NATURE.—THE PROGRESS OF MANKIND.

THE action of man is so powerful an agency in draining marshes and lakes, in smoothing down the obstacles between different countries, and in modifying the primitive distribution of animal and vegetable species, that these very facts become of decisive importance in the changes which the outward surface of the globe is undergoing. This action of man may embellish the earth, but it may also disfigure it; according to the customs and social condition of any nation, it contributes either to the degradation or glorification of nature. Man moulds into his own image the country which he inhabits; after long centuries of reckless use of it, the barbarian gives to the earth he lives on an aspect of rough brutality, whilst by an intelligent system of cultivation, civilization makes the country radiant with grace and with an impressive charm; he may humanize it, so to speak, so that any stranger passing through it feels a welcome when he enters it, and that he may safely repose in its bosom.

As if merely encamped, like a passing traveller, the barbarian robs the soil without returning to it by cultivation and thoughtful care that which he extorts from it; he ultimately succeeds in completely devastating the country which he uses as his place of abode and rendering it uninhabitable. The surface of the earth presents numerous instances of devastation of this kind carried on without mercy for the soil. In many a spot man has changed his native country into a desert, and "the grass has ceased to grow where he has placed his foot." A large portion of Persia, Mesopotamia, Idumea, and various countries of Asia Minor and Arabia, which used "to flow with milk and honey" and once fed a very considerable population, have become almost entirely sterile and inhabited by a few miserable tribes, living by pillage and the most primitive style of agriculture. When the powers of Rome gave way under the attacks of barbarian invaders, Italy and the adjacent provinces, exhausted by the unintelligent labour of slaves, were to a great extent changed into deserts, and even at the present day, after lying two thousand years fallow, vast tracts of land which were brought into cultivation by the Etruscans and the Siculi, are now useless heather or unhealthy marshes. In consequence of causes of a like nature which resulted in the impoverishment and ruin of the Roman Empire, the New World itself has lost, in an agricultural point of view, a considerable portion of its territory; many a plantation in the Carolinas and in Alabama which was reclaimed from the virgin forest not more than half a

century ago, has totally ceased to be productive, and is now nothing more than an abode for wild animals. In Brazil and Columbia, naturally the most fertile countries of the whole earth, a few years are sufficient for exhausting the soil by means of a system of cultivation which is a mere robbery from it. The trees are burnt down, and maize is sown over the ashes, and the same crop is incessantly removed year after year, until it is smothered by a fresh growth of brushwood. This is burnt for the second time, and maize is sown again. Ultimately, ferns and a slimy, fetid sort of grass called *capim gordura* make their appearance, and the land is then destroyed for the purposes of cultivation.

The question as to how far the agency of man serves either to adorn or degrade the aspect of nature may seem an idle one to minds of a so-called positive tendency; but it none the less assumes an importance of the highest order. The development of mankind is bound up most intimately with the surrounding conditions of nature. A hidden harmony springs up between the land and the nation which is nourished by it, and if any society is imprudent enough to lay a disturbing hand on the elements which form the beauty of its territory, it is ultimately sure to repent of it. In a spot where the country is disfigured and where all the grace of poetry has disappeared from the landscape, imagination dies out and the mind is impoverished; a spirit of routine and servility takes possession of the soul, and leads it on to torpor and to death. Among the causes which, in the history of mankind, have led to the extinction of so many forms of civilization, we must place in the first order the reckless violence with which most nations have treated the soil which nourished them. They cut down the forests, exhausted the springs, and made the rivers overflow, and after thus injuring the climate, surrounded their towns with a belt of marshy and unhealthy land; and then, when the nature which they profaned showed its hostility against them, they began to hate it, and being unable like the savage to fall back on forest-life, they allowed themselves to fall into deeper and deeper degradation through the despotism of priests and kings. "Vast domains have been the destruction of Italy" is the opinion of Pliny; but it must be added that these vast domains, being cultivated by the hands of slaves, had disfigured the land like a leprosy. Historians have been struck with the extreme decadence of Spain since the days of Charles V., and have endeavoured to explain it in various ways. In the opinion of some, the chief cause of the ruin which has befallen the nation was the discovery of gold in America; in the opinion of others, the cause was the religious terror organised by the "holy brotherhood" of the Inquisition, the expulsion of the Jews and Moors, or the sanguinary *auto da fé* of heretics. The fall of Spain had been also attributed to the iniquitous impost of the *alcabala*, and to the system adopted from the French of despotic centralization. But is not the kind of madness with which the Spaniard has felled the trees for fear of the small birds, "*por miedo de los pajaritos,*" a point to be considered in this terrible decadence? The land has become yellow, stony, and bare, and has assumed a repulsive and frightful aspect; the soil is impoverished, and the population, which for two centuries has been diminishing, has partially relapsed into barbarism. The small birds are well avenged.

Even in our own days and among nations the most advanced in civilization, numbers of the works of man have been attended with the fatal result of impoverishing the soil and disfiguring the face of nature. Taken as a whole, mankind has not yet emerged from his primitive barbarism. The work of deterioration assumes a different aspect among different nations according to their systems of agriculture, the variety of climates, and the diversity of manners and of national character.

Arabs, Spaniards, and Spanish-Americans completely fell the trees and leave the face of the country to dry up and become yellow in the sun ; Italians and Germans, on the other hand, scandalously mutilate the trees which they do not cut down, and give them the aspect of posts or broomsticks; the French divide their land into innumerable parcels producing different kinds of crops, which looked at from a distance on the hillsides resemble many-coloured draperies spread upon the soil. In the United States the land is cut up into geometrical squares, all uniform and with similar bearings, in spite of the undulations and risings of the ground. Lastly, in some countries the proprietors of land, either poor peasants or great lords, surround their domains with defensive walls and hem them in with ditches as if they were besieged fortresses. This is done even by the miserable Irishman, the poorest among men, who encloses with a high earthen bank his bit of garden-ground containing nothing but ill-growing plants. How many countries there are in Europe through which one may travel for whole hours without finding a single spot on which an artist's glance might rest with any degree of satisfaction !

There are others besides the "rough tiller of the soil," so jealous of his patrimonial landmarks and so pre-eminently eager to obtain abundant products, who are often at work in disfiguring the aspect of the land in which they live ; indeed, some of those who profess the greatest admiration for nature are in the habit of systematically degrading the most beautiful sites. In the environs of towns, the districts supposed to be country are cut up into enclosures, and are only represented by closely shorn shrubs, and beds of flowers of which a glimpse may be obtained through iron railings. Many of the German princelings, vitiated by a foolish sentimentalism, have defaced the most charming landscapes by carving pedantic inscriptions on the rocks, by adorning their lawns with fanciful tombs, and by making their soldiers mount guard in front of the points of view which they desire to point out to strangers. Multitudes of French *bourgeois*, in their mean love for a cramped and symmetrical style, have gone so far as to check the rise of the sap in the trunks, in order to create dwarf varieties and to give to trees geometrical forms or the fantastic appearance of monsters and demons. The grave Dutch merchants of the last century were not satisfied with their garden walks unless they were edged with lime-trees having their heads clipped into the shape of a ball and their trunks coloured white ; and the trees at Brouck are still painted with oils and zinc-white. The gardeners of the Emperor Yang-Ty were in the habit of replacing the flowers and leaves which fell from the trees by artificial foliage and flowers made of silk, the latter being impregnated with perfume so as to render the illusion more complete.

And how far do the highest aspects of nature find their due recognition among us ? On the sea-coast, our most picturesque cliffs and our most charming shores are, in many localities, monopolized either by jealous proprietors or by speculators who appreciate the beauties of nature in much the same way as a money-changer values an ingot of gold. In much-frequented mountain districts a similar rage for appropriation takes possession of the inhabitants : the landscapes are cut up into squares and sold to the highest bidders ; every natural curiosity, the rock, the cave, the waterfall, the glacier, everything, down even to the sound of an echo, may become private property. The very cataracts are farmed out to contractors, who surround them with wooden fences in order to prevent non-paying travellers from contemplating the tumult of the waters, and then, by dint of laudatory articles in the public press, coin, as it were, the very light which plays in the broken water-drops, and the break of the wind which spreads clouds of mist over the abyss, and

convert them into hard ready cash. No traveller can fail to experience a feeling of deep mortification when he compares the Niagara of to-day, such as men have made it, with the former "thunder of the waters," when it was left in the simplicity which nature gave it to us. Hideous buildings, mills, workshops, hotels, and warehouses, have taken root on the cliffs; advertisers, speculating on the beauty of Niagara for the sale of their merchandise or of their drugs, have posted up their dirty and lying placards in front of the roaring cataract; other persons, still more disagreeable in their ingenuity, have vainly attempted to add some poetical features to the scenery by erecting Chinese kiosks and Gothic turrets. The trees and their verdure, which formed so appropriate a framework to the white hue of the water, have fallen under the stroke of the axe, and the body of water itself is diminishing every day owing to the side channels which are dug by the millowners to draw water from the Niagara for driving their machinery. Let the energy of man utilize, if it will, the immense power of the cataract; nothing can be more advantageous. But in this work of improvement the beauty of the spot has not been respected. Recently, however, a revulsion of feeling has set in, and measures have been adopted for protecting the landscape from further damage and gradually restoring it to its pristine condition.

Under the rude hands of the conquerors of Rome and during the unhappy period of the middle ages, the thousands of slaves who cultivated the soil were but little able to comprehend the beauty of the land on which their miserable lives were spent; and any sentiment that inspired them with respect for the scenery which surrounded them must necessarily have been of a vitiated character. The bitterness of existence must then have been much too intense for them to experience any pleasure in admiring the passing clouds, the rocks, and the trees. Then on every side were quarrels, hatreds, sudden terrors, wars, and famines. The caprice and cruelty of the master was the law of the enslaved; in every unknown face they seemed to recognize a murderer; the names of stranger and enemy were then synonymous. In a society of this kind if a brave man wished to combat his destiny and to preserve the self-consciousness of his own soul, the only thing he could do was to be joyous and ironical, to scoff at the strong and especially at his master; but if he contemplated the earth nothing remained for him but grief. The splendour of the loveliest features of nature which surrounded them could not but remain unknown to the men who, influenced by a vague terror, sedulously kept up by sorcerers of every kind, ever fancied that, in every cave, in every deeply-hollowed road, in the mountain-gorge, and in the dim silence of the woods, they could discern hideous ghosts and horrible monsters, partaking of the natures both of the beast and the demon. What strange ideas must have been entertained of the earth and its beauties by those monks of the middle ages, who, in their maps of the world, were always in the habit of drawing, by the side of the name of every distant country, strange animals vomiting out fire, men furnished with horses' hoofs or fishes' tails, griffins with the heads of rams or bulls, flying dragons, and headless bodies with wild staring eyes placed in the middle of their breasts!

When the incessant warfare of the middle ages had come to an end, the desire of every man who had escaped in the conflict must have been to secure for himself some charming and sheltered home; the bolder features of nature only produced fear, and all he asked for was peace. The ideal of the generations, which followed one another from the Renaissance to the French Revolution, is betrayed by the character of the sites chosen by both princes and lords for building their country seats. But a very small number of these palaces occupy a position which affords a

view of a magnificent horizon of mountains and rocks; in many localities, especially on the shores of the lake of Geneva, the country houses built by the rich proprietors of the adjacent land turn their backs to the scenery which now appears to us the grandest. Instead of an aspect of nature too impressive and too wild for him to take pleasure in contemplating it, man then preferred a limited area of view, which the imagination could easily embrace, such as a curtain of gently sloping hills, a little stream winding along under the shade of alders and weeping-willows, charming avenues of clustering trees, and lawns and lakes ornamented by statuary. They valued these elegant graces far above the magnificent simplicity of a widely extending prospect.

The nations who at the present day are placed, in consequence of their pre-eminence in civilization, in the front rank of mankind, take, generally speaking, but very little trouble in the embellishment of nature. Being much more devoted to industrial than artistic skill, they prefer power to beauty. The universal wish of man is to adapt the earth to his requirements, and to take complete possession of it in order to derive from it its immense treasures. He covers it with a network of roads, railways, and telegraphic wires; he fertilizes its deserts and makes himself master of its rivers; he breaks up the rising grounds, and spreads them in the form of alluvium over the plains; bores through the Alps and the Andes, and having united the Red Sea with the Mediterranean, is preparing to mingle the waters of the Pacific with those of the West Indian Seas. Nearly all men, being either agents in, or witnesses of, these vast undertakings, allow themselves to be carried away by the fascination of labour, and their only idea is how they can mould the earth into the image which suits them best. And yet, when man forms some loftier ideal as regards his action on the earth, he always perfectly succeeds in improving its surface, although he allows the scenery to retain its natural beauty. Nature preserves its beauty when the really intelligent agriculturist gives up raising and forcing, as if at haphazard, plants of the most various kinds, on a soil of the properties of which he is ignorant, when, before intrusting to cultivation, he first and foremost comprehends that the land must not be recklessly dealt with, and previously humours it, by finding out the crops best suited for it. Thus, the "Shakers" in the United States, who have made agricultural labour "a ceremony of love," and feel it a duty to cherish the trees which they rear, the seed which they cast into the furrows, and the rivulet which they turn to their purpose, have really succeeded in converting into perfect paradises their estates at Mount Lebanon, Hancock, and Water-Vliet. The inhabitants of the district of Vineland, in New Jersey, have unanimously agreed to remove all fences between their respective garden-plots, orchards, and groves; and the whole nation has resolved, by converting it into a national park, to secure for all time the marvellous region of the Upper Yellowstone river, with its lofty volcanic mountains, its forests, lakes, waterfalls, and innumerable geysers and hot springs.

England is the country in which the agriculturists produce from their fields the most abundant crops; yet its people have always shown more respect for trees than was ever the case with the Latin races, and there also we find but few localities which do not possess a certain amount of grace or even of real beauty owing either to the great oaks standing by themselves and spreading their branches over the meadows, or to the clumps of trees of various kinds dotted about with picturesque art round villages and country houses. The art of man, notwithstanding the opinion of some morose minds, has it in its power to embellish even the aspect of free nature, by giving it the charm of prospect and variety, and

above all by placing it in harmony with the deepest-seated feelings of those who inhabit it. In Switzerland, on the shores of the great lakes, and in front of blue mountains and glittering glaciers, how many instances there are, both of farmhouses and villas which, by their grassy lawns, their clumps of flower-beds, and their shady walks, render the face of nature still more beautiful, and charm as if by some pleasant dream of happiness the traveller who passes by!

Henceforth, owing to the increasing love of travel, the globe itself will become the agent in ennobling the taste of its inhabitants and imparting to them a sense of

Fig. 206.—Yellowstone National Park.

the truly beautiful. Those who traverse the Pyrenees, the Alps, or the Himalayas, or even the high cliffs along the sea-shore, those who plunge into the depths of the virgin forest or look down into a volcanic crater, learn, while looking at these magnificent sights, how to appreciate the true beauty of less striking scenery, and when they have the power of modifying it they will not fail to respect its peculiar features. We must therefore wish every success to that noble passion which impels so many men, and, we must add, the best among men, to penetrate into virgin forests, to traverse sea-shores and mountain-gorges, and to examine nature in all the regions of the globe where she has preserved her primitive beauty. It

is now felt that, unless we wish to subside into intellectual and moral weakness, it is necessary that the vulgarity of so many ugly and commonplace things, in which narrow-minded people think that they discern the evidences of modern civilization, should be counterbalanced at any cost by the contemplation of the magnificent scenery of the earth. It is necessary that the direct study of nature and the consideration of its phenomena should become one of the principal elements of education for every cultivated man ; it is also necessary that skill and muscular energy should be developed in every individual, so that he may be able cheerfully to scale the highest mountain-peaks and look down into their abysses without fear, and also to keep up in the whole of his physical being that natural balance of power, without which the noblest prospects are surveyed only through a veil, as it were, of sadness and melancholy. The man of modern times ought to combine in his own proper person all the virtues of those who have gone before him on the earth ; without surrendering any of the enormous privileges intrusted to him by civilization. It is his duty also to maintain unimpaired all the vigour bequeathed to him, and not to allow himself to be excelled by any savage on the earth in strength, skill, or a knowledge of the phenomena of nature. In the grand times of the old Greek republics, the great object which the Hellenes had in view in the education of their children was to turn them into heroes by means of grace, strength, and courage ; and in like manner, by stimulating all manly qualities in the rising generation, by bringing them face to face with nature, and by leaving them to fight out the battle with her, modern societies of men may insure themselves against the occurrence of any decadence by the regeneration of the very race itself.

A robust education of this kind will give us the grandest development of the real love for nature. Slavery and a spirit of routine may vitiate it ; but knowledge and liberty give it new life. Science, which is gradually converting the globe into one great organism always at work for the benefit of mankind, doing this by means of winds and currents, steam and the electric fluid, is at the same time pointing out to us the means for beautifying the surface of the earth, and for making it that pleasant garden which has been dreamt of by poets in all ages. Nevertheless, although science may bring before our eyes the distant future of a glorified earth, she alone cannot bring to perfection this great work. A moral progress must necessarily correspond with this progress in knowledge. Whilst men are fighting with one another with the aim of shifting the patrimonial boundaries and the imaginary frontiers of their nations ; whilst the soil which nourishes them continues to be reddened with the blood of insensate wretches who wage war either for a paltry strip of territory, or for some question of so-called honour, or incited by a mere lust for conflict, like the barbarians of ancient times, so long will be deferred that paradise on earth which the inquiring mind already seems to contemplate in the distant future. The features of the globe will never assume their perfect harmony until men are united in one league of justice and of peace. Ere she can become truly beauteous our "beneficent mother" must wait until her sons have all embraced as brothers, and have succeeded in establishing the grand confederation of free nations.

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THE END.

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